STRATIGRAPHY OF THE DEVONIAN HARRELL AND MILLBORO SHALES IN PARTS OF PENNSYLVANIA, MARYLAND, WEST VIRGINIA AND VIRGINIA

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ABSTRACT

The regional stratigraphic relationships among the Devonian Harrell and Millboro Shales and part of the Mahantango Formation are summarized in a series of stratigraphic cross sections based on 162 outcrop and subsurface data points.

The study area covers approximately 15,000 square miles in the folded Appalachian part of Pennsylvania, Maryland and the Virginias and the subsurface west of the Allegheny Front.

The grayish black Millboro Shale fills the Tioga Bentonite to base of Brallier interval west of a line between Cambria County, Pennsylvania and Rockingham County, Virginia. East of this line, the silty, gray shale of the Mahantango Formation forms a wedge which splits the main mass of Millboro into the grayish black Marcellus Shale below and the dark gray Harrell Shale (with a lower black Burket Member) above.

The Mahantango thins and changes facies southwestward, passing into the middle of the black Millboro Shale and is not recognizable southwest of the Grant-Pendleton County, West Virginia border. The base of the Brallier Formation is marked by the introduction of turbidite siltstones into the shale sequence.

Several units within the shale sequence approximate time markers. These units are, in stratigraphically younger succession: the Tioga Bentonite, Purcell Limestone, the Landes Limestone and its corresponding zone of concretions, an unnamed siltstone between the Chaneysville and Clearville Members of the Mahantango, the Tully Limestone, the base of Brallier along Allegheny Front and the Back Creek Siltstone.

INTRODUCTION

The dark Devonian Shales of the Appalachian Basin have become a major topic of geologic investigation in recent years as a result of the national energy shortage and the Energy Research and Development Administration's effort to increase hydrocarbon production from these rocks. The strata involved are part of the Devonian Catskill delta system and involve complex east-west facies changes with attendant nomenclatural complexity and confusion. Until recently there has been relatively little interest in relating outcrop and subsurface information in a three-dimensional network to interpret properly the regional facies relationships over a large area.

The present investigation is such a three-dimensional study, which summarizes both in text and a series of stratigraphic cross sections the work begun by us in 1965 to interpret the stratigraphy of the Devonian "black shales." Initially our work was limited to the Allegheny Front outcrop belt, but has expanded over the years to include the eastern outcrop belt and the subsurface west of the Allegheny Front. The results of this on-going work have been reported in a series of papers and oral presentations (Hasson, 1966, 1972b; Hasson and Dennison, 1967, 1973, 1974, 1978 (in press); Hasson and Liebe, 1968; Hasson and Cocke, 1973; Dennison and Hasson, 1974, 1976, 1977a, 1977b (in press).

The study area includes parts of Pennsylvania, Maryland, West Virginia and Virginia. The outcrop belt studied is approximately 196 miles (314 km) long; the entire project area encompasses some 14,720 square miles (37,632 km^2); some 162 data points were utilized in the

study. The area and the location of data points used in the study are shown in Figure 1. Lines of stratigraphic cross sections are also shown on the figure. The outcrop data are from measured sections exposed in the folded Appalachian portion of the above states.

The original data were compiled at a scale of about eleven feet per inch. In the accompanying cross sections they are plotted at a scale of 100 feet per inch with resultant loss of some stratigraphic details; however, this scale is compatible with that of Geologs. Well data are from the published literature, the files of the West Virginia Geological and Economic Survey, the Pennsylvania Geological Survey, the Maryland Geologic Survey, Hope Natural Gas Company, Consolidated Gas Company and sample examinations by Dennison. The location of each data point is given in Appendix B. Four of the sections in this study are type sections and are described in detail in Appendix A.

The principal stratigraphic units with which this study is concerned are the Harrell and Millboro Shales. The Millboro Shale occupies the interval between the Tioga Metabentonite and the Brallier Formation west of a generally north-south line between Cambria County, Pennsylvania and Rockingham County, Virginia (Figure 3). To the east of this line the mass of black shale is split by a wedge of silty gray shale (Mahantango Formation) which continues to coarsen eastward. Where this wedge of silty shale is present it is possible to divide the Millboro into grayish black Marcellus Shale below and the dark gray Harrell Shale (with a lower grayish black Burket Member) above. During this study it became obvious that at least some portions of the Mahantango and Brallier formations had to be included in our measurements if the regional relations of the

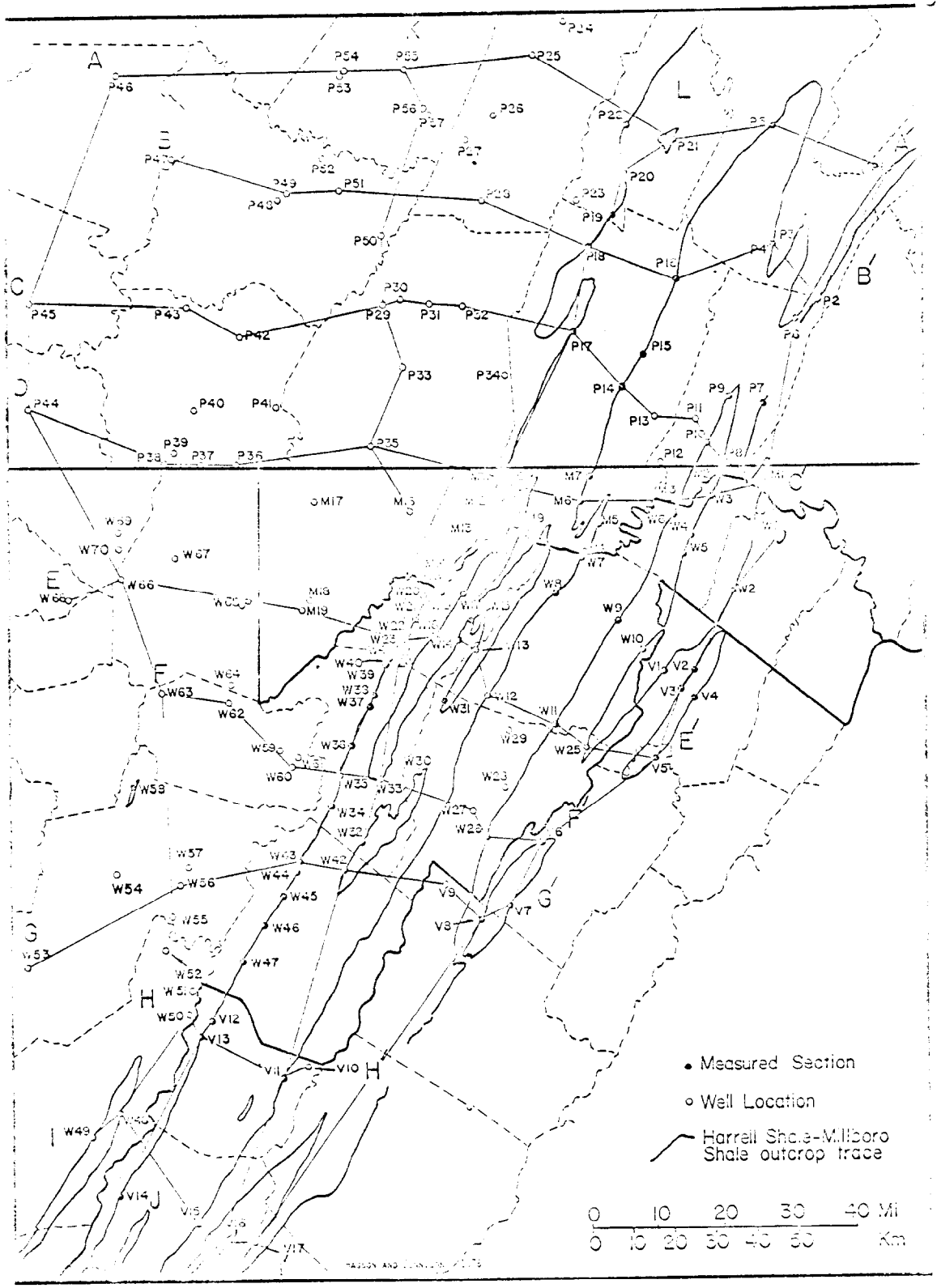

Figure 1. Map of project area showing Harrell-Millboro outcrop trace, data points used in this study and lines of stratigraphic cross sections which are included later in the report.

Harrell and Millboro shales to these units and to each other were to be understood. Accordingly, most of the cross sections include some portions of our data on the Brallier and Mahantango Formations.

The initial results of this investigation constituted a thesis completed at the University of Tennessee (Hasson, 1966), a copy of which is on file with the Pennsylvania Geological Survey and the West Virginia Geological Survey; the latter organization underwrote most the field expenses. Field work subsequent to completion of the thesis was supported in part from our personal funds and a grant to Dennison from the Research Council of the University of North Carolina. Compilation of this specific report was a project of the United States Energy Research and Development Administration.

ACKNOWLEDGEMENTS

An expression of appreciation is due several people. Philip Heckel, University of Iowa, identified certain fossils and discussions with him concerning the Tully Limestone were quite valuable. Professor M. R. House of University of Hull, England, identified and made age determinations of some Tully ammonoids. The late John Huddle identified Tully conodonts for us. The task of locating well data was eased greatly by the help of Louis Heyman (Pennsylvania Topographic and Geologic Survey) and Douglas Patchen (West Virginia Geological and Economic Survey). Judy Oaks typed both the rough and final copies of the report. Drafting was done by Larry Woods and Mark Hicks.

STRATIGRAPHY

Introduction

The designation and stratigraphic rank of the units in the project area have undergone numerous changes over the years. The complex stratigraphic nomenclature, generally proposed by workers on the basis of variation in the local section and without benefit of a regional experience, has resulted in general nomenclatural confusion and sometimes actual misinterpretation of the stratigraphy. Perhaps the chief culprit in the confusion is that the strata involved are part of an extensive deltaic complex and represent depositional environments, not only on a deltaic lobe, but in embayments marginal to the lobe. Interbedded distally and marginally with the coarser, nearer shore clastics are the finer, generally darker, more organically rich offshore sediments. Since this is not a static system, shoreline shifts through time are inevitable, with accompanying shifts of sedimentary facies to further complicate the problem.

Establishment of a suitable nomenclatural scheme involves the deciphering of the general east-west facies changes of the Hamilton and Portage Groups across the area of the Fulton Lobe. The Fulton Lobe is the southermost of three Devonian deltaic distributaries recognized by Willard (1934, 1939) in Pennsylvania. Willard chose the name for the lobe from its development in Fulton County, Pennsylvania. Figure 2 is a map showing the Late Devonian position of the Fulton Lobe as interpreted by Willard, with its configuration at the specific time of the Harrell Shale as interpreted by us from more extensive data than available to

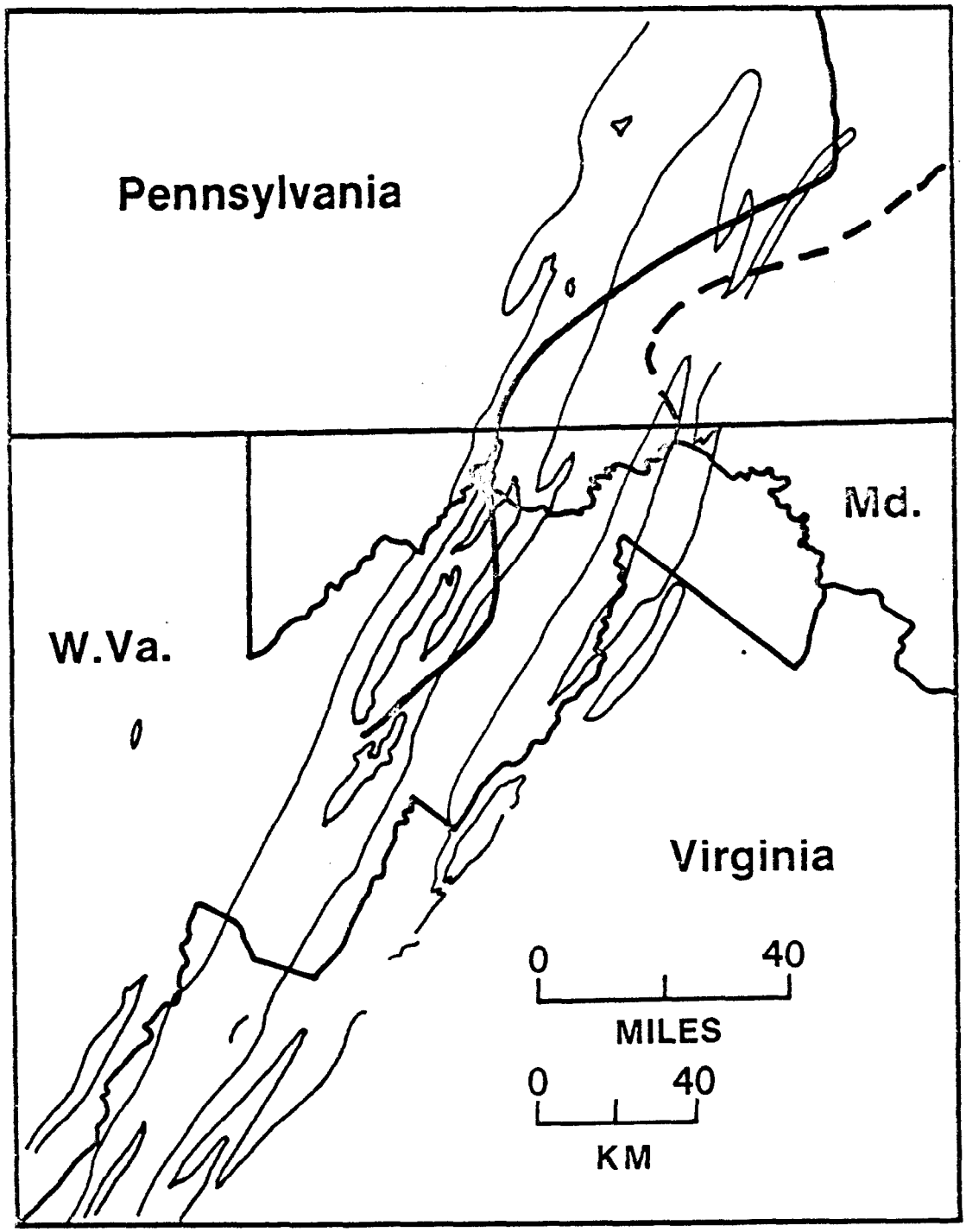

Figure 2. Map of project area showing configuration of Fulton Lobe as envisaged by Wallard (dashed line) and as interpreted by us in this report (solid line)

Willard, super-imposed. Figure 3 indicates the general geographic areas of application of certain Devonian Shale nomenclature in the Appalachians.

The regional stratigraphic details are illustrated by cross sections and are discussed in a later section of this report. In this section we will describe the lithic characteristics of the units. Because of the facies changes over the area, it is convenient to consider the stratigraphy divided into three belts: an eastern belt, a central or Allegheny Front belt and a western belt, which is mostly subsurface. The eastern belt includes the area of easternmost Huntingdon and Fulton Counties, Pennsylvania; Washington County, Maryland; Morgan, Berkeley and easternmost Hampshire and Hardy Counties, West Virginia; and Frederick, Shenandoah and Rockingham Counties, Virginia. The Allegheny Front belt includes those outcrop belts west of the eastern belt and west to the Allegheny Front. The western belt includes the subsurface area west of the Allegheny Front and because of lithologic similarity, the outcrop belts in Pocohontas County, West Virginia and Highland and Bath Counties, Virginia. The boundaries of these areas are shown in Figure 4.

In the following descriptions we will discuss the units from youngest to oldest, that is, in the order of drill penetration, beginning with the eastern belt. Figure 5 is a map showing the locations of type sections of the formations and members described in this report.

EASTERN BELT

The section in the eastern outcrop belt lacks the dark shale of the central belt, and the Brallier Formation rests directly on the Mahantango Formation. The units recognized in this belt are:

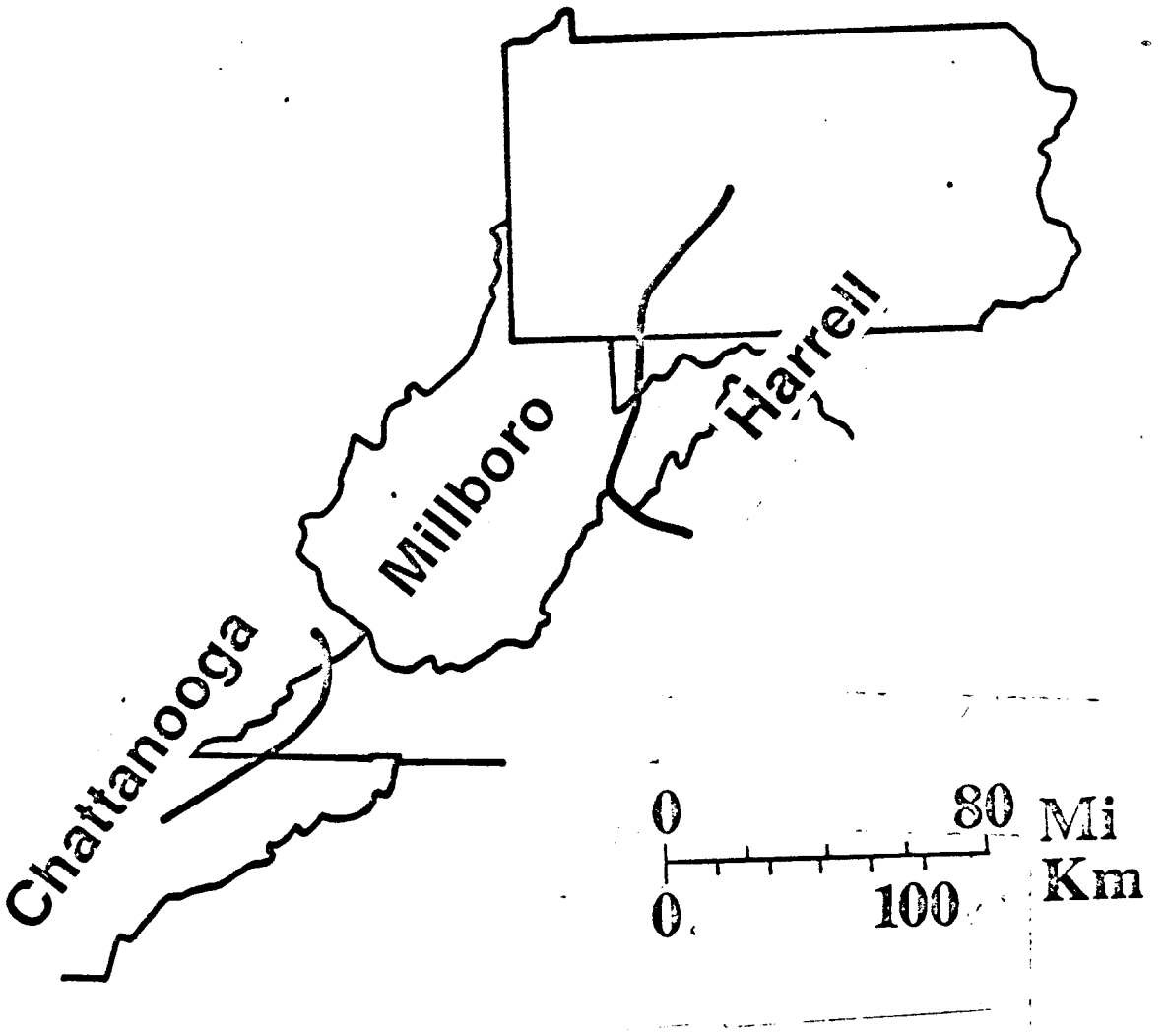

Figure 3. Areas of application of certain Devonian Shale names.

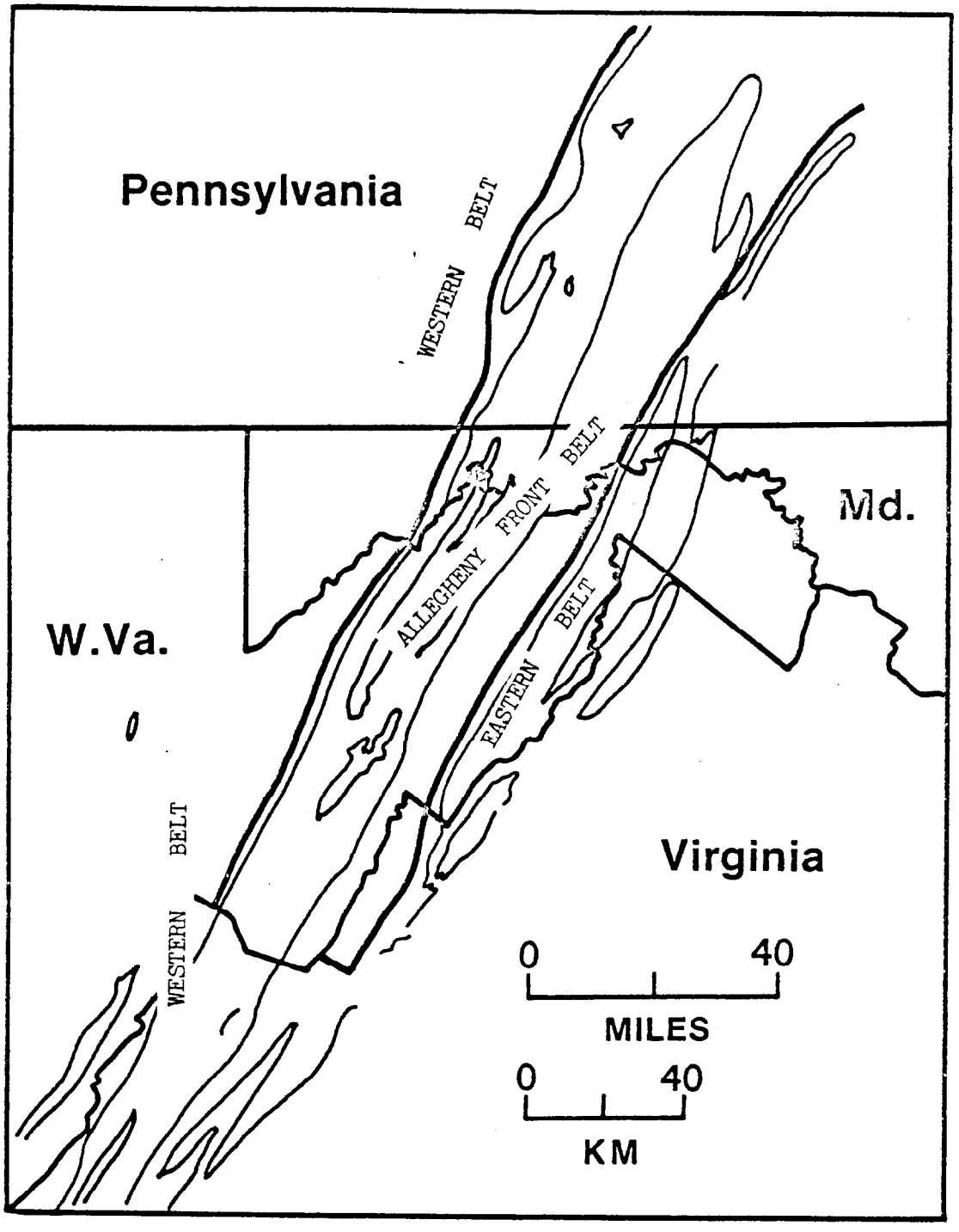

Figure 4. Boundaries of stratigraphic areas as discussed individually in the text.

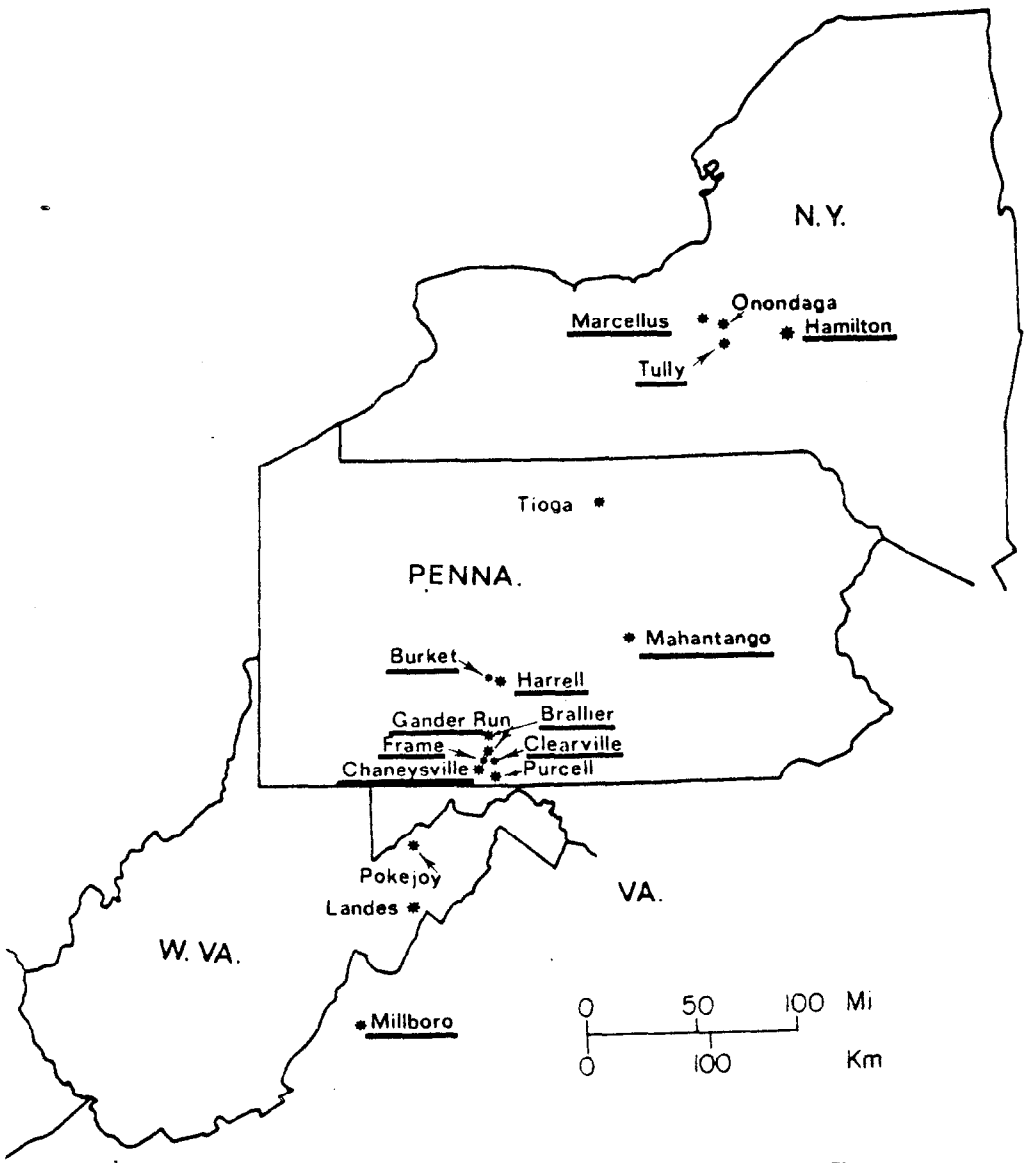

Figure 5. Map of Appalachian area showing the locations of type sections of stratigraphic units mentioned in the text.

Brallier Formation

Mahantango Formation

Unnamed shale

Clearville siltstone (informal)

Unnamed siltstone

Frame Shale Member (restricted)

Chaneysville Siltstone Member

Gander Run Shale Member

Marcellus Shale

Purcell Member (informal)

Tioga Bentonite

Brallier Formation

The Brallier formation is the uppermost of two formations proposed by Charles Butts (1918, 1945) in his revision of the Portage Group in the Hollidaysburg-Huntingdon Folio area of Pennsylvania. The Portage Group extends from the top of the Hamilton Group (Mahantango Formation of present usage) to the base of the Chemung Sandstone. The Brallier Formation was named by Butts (1918) for exposures near Brallier Station, a stop on the Huntingdon and Broadtop Mountain Railroad about five miles northeast of Everett, Bedford County, Pennsylvania.

The formation consists of interbedded shale and siltstone. The shale is thickly laminated, medium dark gray on fresh outcrops and weathers to characteristic olive or light olive gray chips. The siltstones generally are in sharply bounded beds ranging from about 0.1 foot (.03m) to about one foot (0.3m) thick. Although light to medium gray on fresh

surfaces, the beds commonly are yellowish gray or rust-color on the weathered surface. The siltstones have characteristics attributable to turbidity flow. They are commonly cross-laminated and in the area of the eastern belt show convoluted bedding, as at an exposure in cuts on West Virginia 55 near Wardensville, Hardy County (W11). It is in this exposure that the most eastern vestiges of the Harrell Shale can be seen interbedded with Brallier siltstone through an interval of 54 feet. The full thickness of the Brallier in this area was not measured by us; however, Butts (1940) reports a thickness of about 1500 feet near Gore, Frederick County, Virginia.

Throughout the project area we use the lowest distinctly bounded siltstone succeeded by interbedded olive shale and siltstone as the base of the Brallier. In outcrops of the eastern belt the Brallier rests directly on the Mahantango. Here, the lowest distinct siltstone overlying the silty, lumpy-weathering olive shales of the Mahantango is taken as the contact. This relationship is particularly well exposed at Burnt Cabins (P2), Fort Littleton (P6) and Harrisonville Road (P13) in Pennsylvania; in Maryland at Pectenville (M1) and Hancock (M2); and in Virginia at Chambersville (V4).

Mahantango Formation

In New York the Hamilton Group (Vaunexum, 1840) includes, in ascending order, the Marcellus, Skaneateles, Ludlowville and Moscow Formations. The name Mahantango was introduced by Willard (1935a) to include the strata between the Marcellus Shale and the Portage Group, and is equivalent to the Skaneateles, Ludlowville and Moscow Formations of the New York outcrop belt. Willard introduced the term because he could not

recognize separately the New York formations in Pennsylvania.

The name is taken from the north branch of Mahantango Creek, Snyder and Juniata Counties, Pennsylvania. In easternmost outcrops the Mahantango is bounded below by the Marcellus Shale and above by the Brallier Formation.

The Mahantango in eastern outcrops is thicker and coarser than to the west. This is because of proximity to the source in the project area and also happens to coincide approximately with the axis of the Fulton Lobe. There have been changes in Hamilton nomenclature over the years which involve recognition of subdivisions within the formation. We have proposed previously a nomenclatural scheme for the Hamilton Group (Dennison and Hasson, 1974, 1976) and published a stratigraphic cross section extending across the project area which shows the relationship of the Hamilton (Mahantango) subdivisions to each other and to bounding strata, reproduced here as Figure 6. This illustration is reproduced later in this report as section D-D', in redrafted form to comply with ERDA requirements for consistency in the Devonian shale project.

The Mahantango Formation consists of very thickly laminated, perhaps even structureless (bioturbated) silty shale with considerable interbedded siltstone and minor limestone. The name Mahantango replaces Hamilton of early geologic reports and is the official terminology used by the Pennsylvania, Maryland and West Virginia geological surveys. There are three distinct siltstone units within the Mahantango, and their recognition and correlation constitute the crux of Mahantango stratigraphic problems.

In descending order beneath the Brallier the Mahantango in the

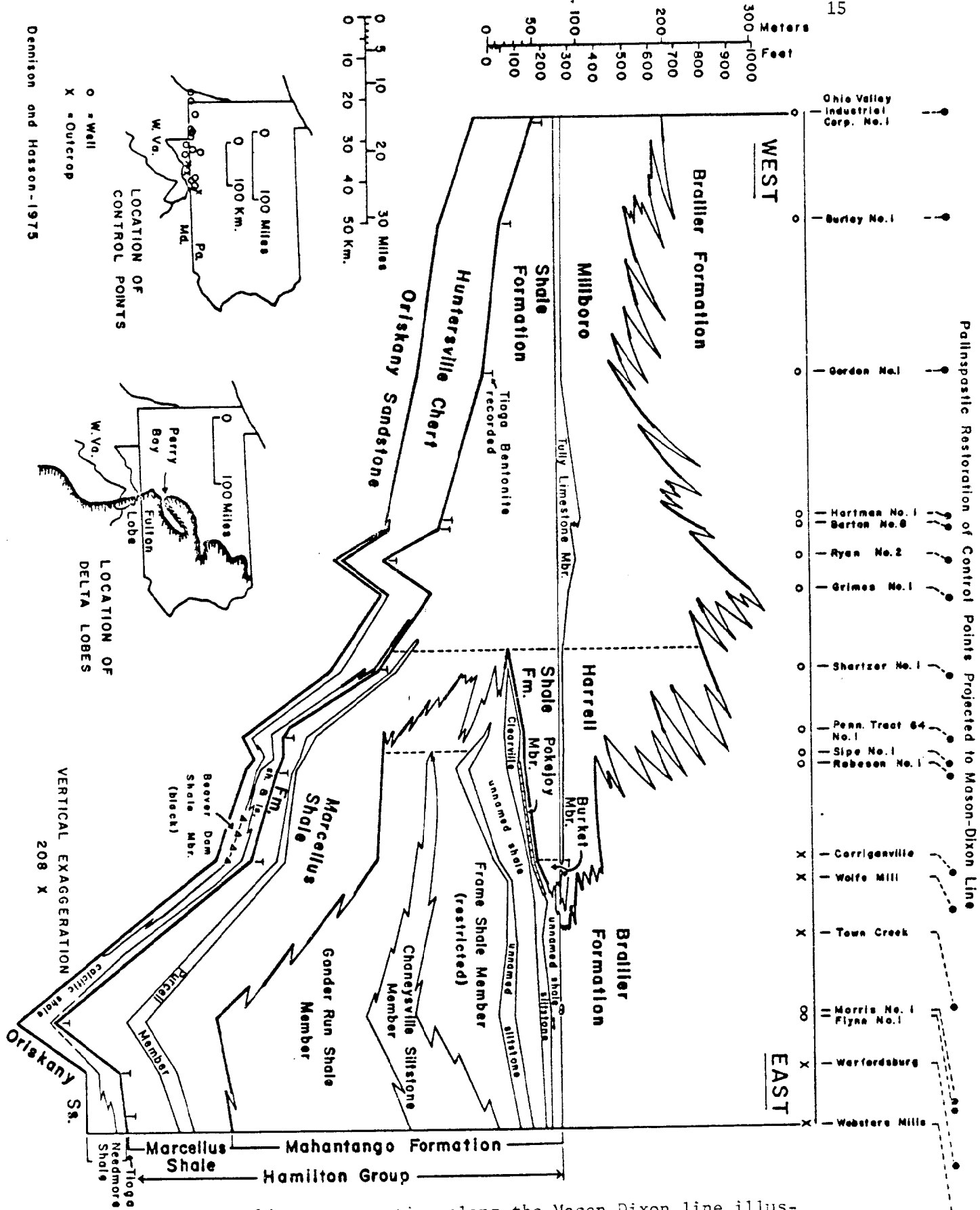

Figure 6. Stratigraphic cross section along the Mason-Dixon line illustrating the nomenclatural and facies relationships of units within the Mahantango Formation and adjacent strata. (After Dennison and Hasson, 1976).

eastern outcrops consists of an unnamed olive silty shale, the Clearville siltstone member (an informal unit) another unnamed shale, an unnamed siltstone, the Frame Shale Member, the Chaneysville Siltstone Member and the Gander Run Shale Member.

Unnamed Shale. Typically the unnamed shale of the upper Mahantango is silty, olive to light olive gray and weathers into lumps and chips. Lamination is generally lacking or poorly developed.

Clearville Siltstone Member. The Clearville Siltstone member (Cate, 1963) is the uppermost of the siltstones in the Mahantango. It is also the most westward extension of Mahantango and its pinchout defines the westernmost recognizable Harrell Shale, and also the limit of the Mahantango Formation. Figure 7 shows the extent of the Clearville in the study area and also the western limit of recognizable Mahantango Formation. The Clearville was described by Cate as the uppermost of two siltstones present in the subsurface of the Clearville, Pennsylvania quadrangle. An outcrop standard reference section of the Clearville has never been formally described, and is beyond the present scope of this report. The upper siltstone is separated from the lower siltstone by about 60 feet (18m) of silty shale in an interval of some 200 feet (61m) (Cate, 1963 Figures 2, 3). The lower siltstone and intervening shale are as yet unnamed; also, the term Clearville is informal.

The term Clearville should be formalized, and a type section established; the lower siltstone and intervening shale should also be designated formally to prevent confusion and to ease communication. For example, Ellison (1965, pl. 2) included both siltstones and the intervening shale as "Uppermost Clearville siltstone" and also placed these

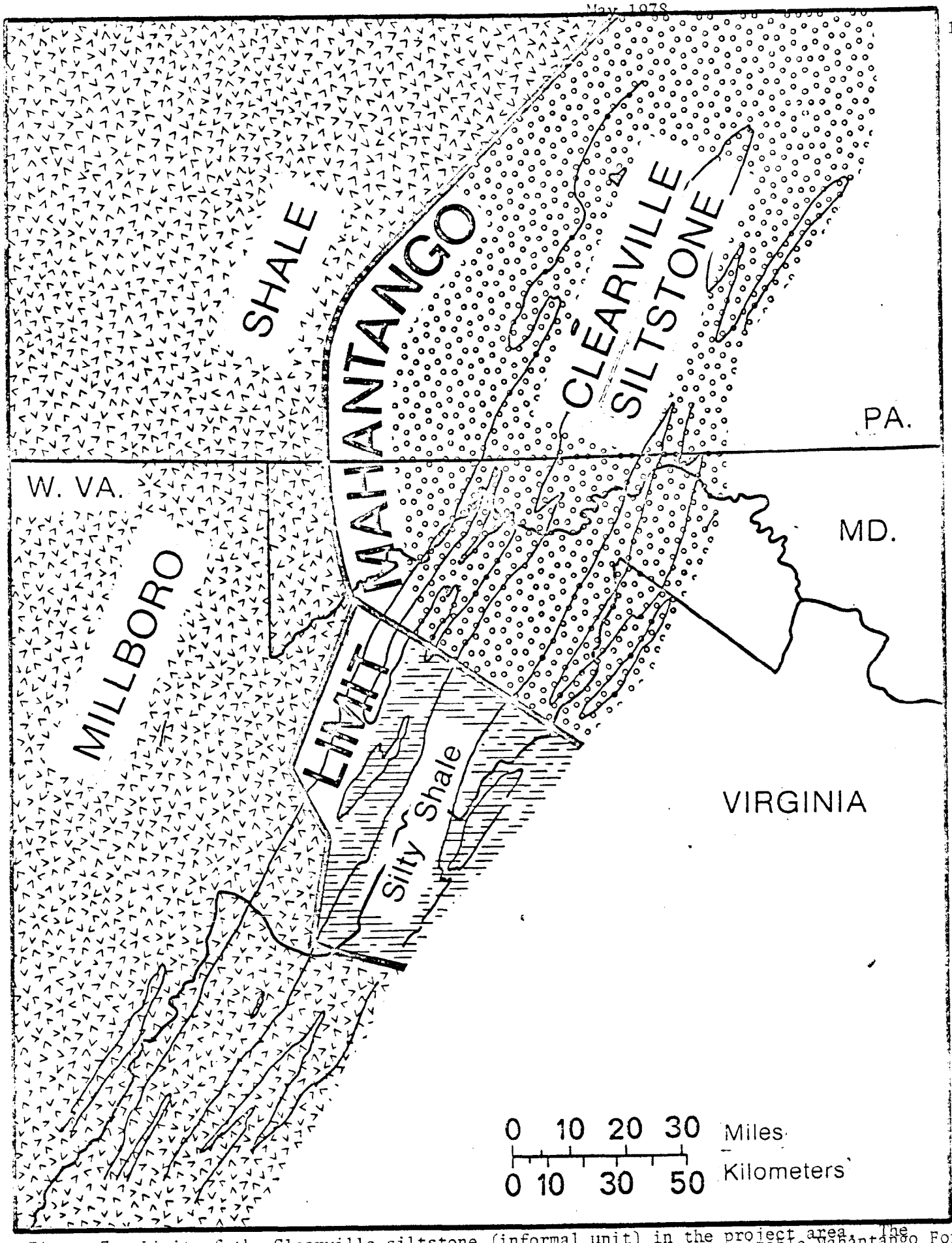

Figure 7. Limit of the Clearville siltstone (informal unit) in the project area. The western limit of the Clearville corresponds to the limit of recognizable Mahantango Formatio

beds in the Frame Shale Member. Obviously, there is a need for clarification of upper Mahantango stratigraphy.

Frame Shale Member. The Frame Shale Member of the Mahantango was named by Willard (1935c) for Frame School, about 6 miles north of Chaneysville, Bedford County, Pennsylvania. He described the Frame (p. 1279) as "gray to olive sandy shale which carries thin, local sandstones and an occasional thin limestone lens." The Clearville position is covered in the main exposure at Chaneysville, so Willard never saw the uppermost siltstone subsequently designated Clearville by Cate. Consequently, as defined by Willard, the Frame Shale extends upward to the base of the Tully, Burket or Harrell, and the Clearville is a member within a member, clearly a violation of the Stratigraphic Code.

In our opinion, for improved nomenclatural clarity the name Frame Shale should be restricted to the strata between the top of the Chaneysville Siltstone below and the base of the presently unnamed siltstone about 100 feet (33m) below the Clearville siltstone as designated by Cate (1963) and illustrated by him in Figures 2 and 3. This is also the lower of two siltstones illustrated and identified as Clearville by Ellison (1965, pl. 2). Restriction of the Frame Member, as we suggest, allows maximum clarity in tracing stratigraphic horizons and avoids violation of the Stratigraphic Code; this is the procedure we followed previously (Dennison and Hasson, 1976).

Chaneysville Siltstone Member. The Chaneysville Siltstone (Willard, 1935c)was named for exposures at Chaneysville, Bedford County, Pennsylvania. The unit was originally designated as Chaneysville Sandstone, but the work was done at a time when all massive clastic units were

called sandstone and siltstone was not used as a separate descriptive term. The Chaneysville was originally described (Willard, 1935c, p. 1279) as "....hard, olive-gray, brown-weathering platy to submassive sandstone...." The Chaneysville does not extend as far west into the Appalachian Basin as the Clearville siltstone. The Chaneysville is limited to the Fulton Lobe (Dennison, 1970, p. 66; 1971, p. 1181; Dennison and deWitt, 1972). The distribution of the Chaneysville Siltstone in the project area is shown in Figure 8.

Gander Run Shale Member. The Gander Run Shale is the lowest member of the Mahantango Formation and was named by Willard (1935c) for Gander Run, a stream six to eight miles north of Chaneysville, Bedford County, Pennsylvania. It was originally described as a dark gray, sandy shale, but more properly should be termed a silty, gray shale. A thickness of 850 feet is given by Willard for the member in the type area.

Marcellus Shale

The Marcellus Shale (Hall, 1839) is the lowest formation of the Hamilton Group in New York; in the eastern part of the project area it underlies the Gander Run Shale Member and in the west is below the silty shale basinward projection of the upper part of the Mahantango Formation. Typically, the Marcellus is grayish black, thinly laminated, platy to sheety-weathering shale. Within the Marcellus is an interval of calcitic shale and limestone which was designated informally by Cate (1963, p. 232) as the Purcell limestone. The term "Purcell Member" appears more appropriate because of the mixed lithology. The Purcell is almost continuously present from central Pennsylvania south to Montgomery County,

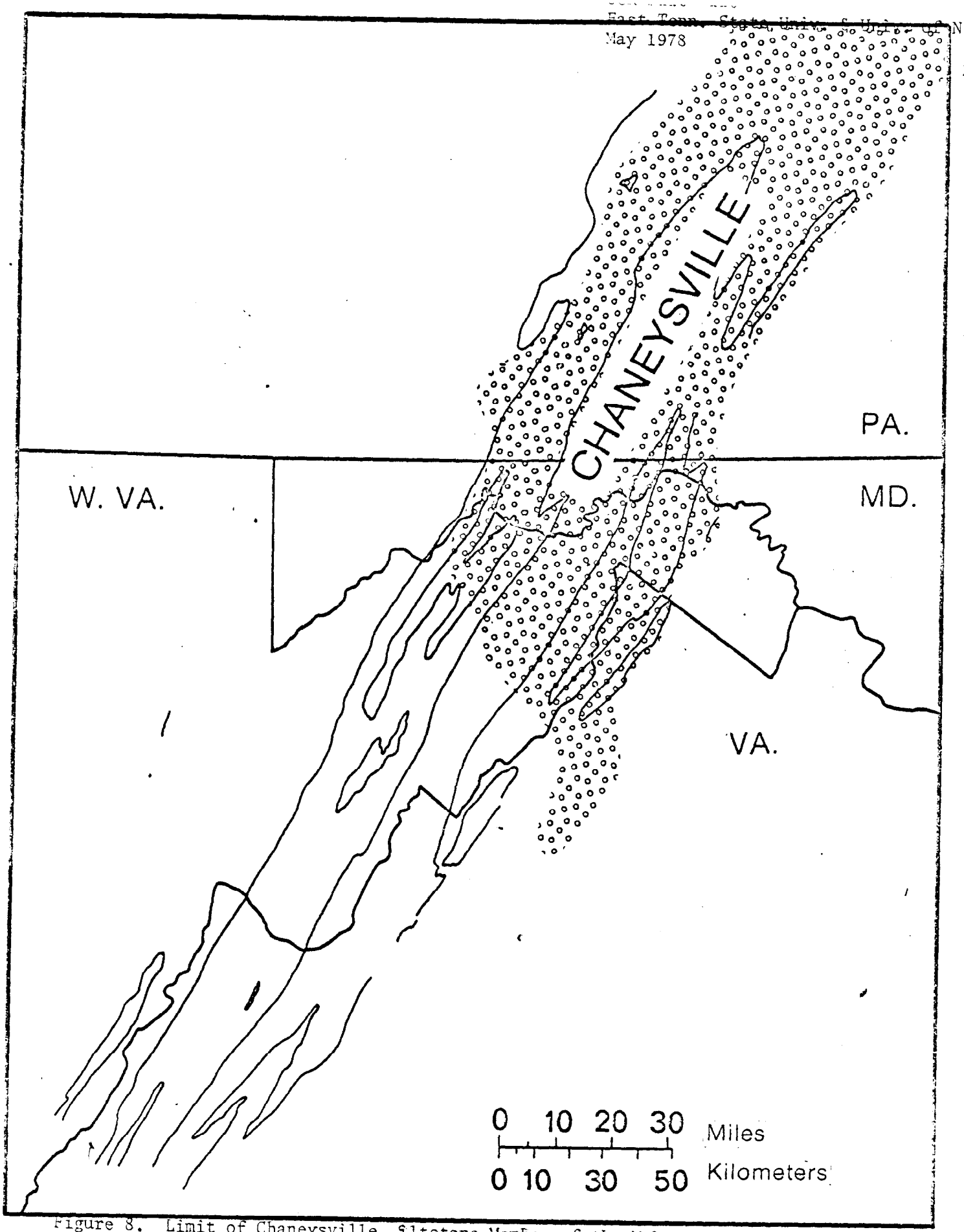

Figure 8. Limit of Chaneysville Siltstone Member of the Mahantango Formation in the project area.

Virginia and forms a convenient marker within the Marcellus and Millboro Shales. The Purcell is absent in the western part of the project area as well as in outcrops of extreme southwest Virginia.

Tioga Bentonite

The Tioga Bentonite is an ash fall characterized by three sand-sized tuffs within a two foot (.6m) interval. The middle coarse zone occurs at the boundary between the Needmore and Marcellus Shales in the north and the Needmore and Millboro Shales in the south. The Tioga ash fall normally produces a brownish (tuffaceous) shale with an Ambocoelia fossil hash; the brownish coloration extends for several feet into the underlying and overlying formations, until the influence of Tioga tuffaceous admixture in the shale can be recognized no further.

ALLEGHENY FRONT BELT

The stratigraphy of the Allegheny Front Belt is more complex than that of the eastern belt. The Mahantango Formation changes facies to the north-northwest across structural strike as well as in a northeast-southeast direction along strike. It is in this area that the coarser Mahantango clastics are replaced upward by fissile, black Marcellus-type shale. The facies changes are coupled with an eustatic sea level rise over the Fulton Lobe which shifts the deeper water, finer grained, more organically rich shales eastward. The eastward shoreline shift is responsible for the creation of Perry and Grant Bays marginal to the Fulton Lobe. These changes in shoreline have resulted in a set of nomenclature applicable both along and across strike. Details of shale stratigraphy along Allegheny Front have been provided by Dennison, 1963;

Hasson, 1966, 1972; Dennison and Hasson, 1976, 1977b (in press); and Hasson and Dennison, 1978 (in press). The units recognized in this area are shown schematically as Figure 9.

Brallier Formation

The Brallier Formation (Butts, 1918) everywhere overlies the Harrell or Millboro Shale in the Allegheny Front belt. It maintains its monotonous lithic characteristics of olive-weathering shale and interbedded, sharply bounded, blocky weathering siltstones. Dennison (1963) reports a thickness of 2000 feet at Corriganville, Maryland (M11) and 1300 feet at Scherr, Grant County, West Virginia (W37). Woodward (1943) gives thicknesses of 1780 feet at Knobly, Mineral County (W18) and 2410 feet near Marlinton, Pocohantas County. As before, we use the lowest distinct siltstone as the base of the Brallier. However, in this area the contact with the underlying Harrell is gradational.

Harrell Shale

The Harrell Shale was named by Butts (1918) for exposures at Horrell Station in Blair County, Pennsylvania on the Petersburg Branch of the Pennsylvania Railroad (P21). The name was apparently transcribed with a spelling error; the location of the now-demolished station is given as Horrell on the Hollidaysburg-Huntingdon folio (Butts 1945) and the station-master at Hollidaysburg assured Hasson in 1965 that the name had always been Horrell. However, Harrell is a well-established geologic name and should be retained; it is now official usage of the Maryland Geological Survey for part of the Jennings Formation (abandoned) and the West Virginia Economic and Geologic Survey for rocks previously termed

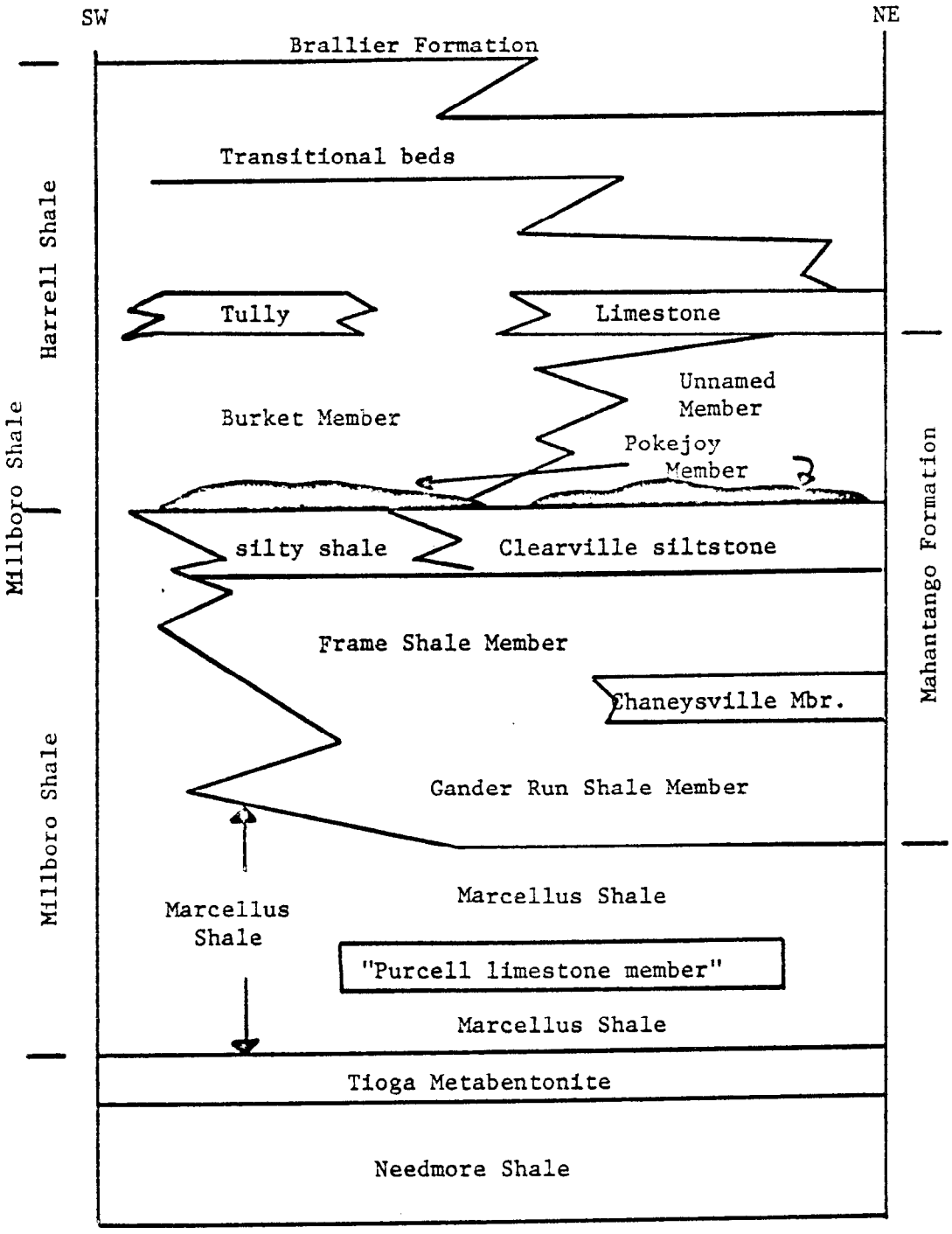

Figure 9. Stratigraphic Nomenclature in the Allegheny Front Outcrop Belt.

Genesee. The type section of the Harrell is described in Appendix A. The Harrell Shale crops out in the fold belts east of the Allegheny Front. The formation averages about 240 feet (83m) thick in the central part of the outcrop area, but thins and grades eastward into coarser clastics of the upper part of the Mahantango Formation and the basal Brallier. In the subsurface west of the Allegheny Front and to the southwest along strike the Harrell passes laterally into the thicker and generally darker mass of the Millboro Shale and is not separable as a distinct formation. The distribution of the Harrell Shale is shown in Figure 10. The reader should note that the western and southern limits of the Harrell correspond to the limits of the Mahantango Formation as shown in Figure 7.

The Harrell Shale consists of very dark gray, thinly laminated, platy- to sheety- weathering shale underlain in certain areas by the grayish black shale of the Burket Member. The Harrell is everywhere overlain by the olive shales and siltstones of the Brallier Formation and is underlain in certain areas by the Tully Limestone, or where the Tully is absent, by the Middle Devonian Mahantango Formation.

In the project area along Allegheny Front the Harrell ceases to be a distinct unit south of southern Grant County, West Virginia. The most southern clear vestige of Harrell occurs at the Hopeville Gap north section (W35), although Hasson (1966) earlier thought that he could recognize it faintly at Mouth of Seneca. Eastward of the Allegheny Front in Pendleton County, we can trace the Harrell to the approximate position of the Pendleton County, West Virginia-Highland County, Virginia border, and we draw the nomenclatural limit at the state line here. The Harrell is traceable farther south in this area than along the Front

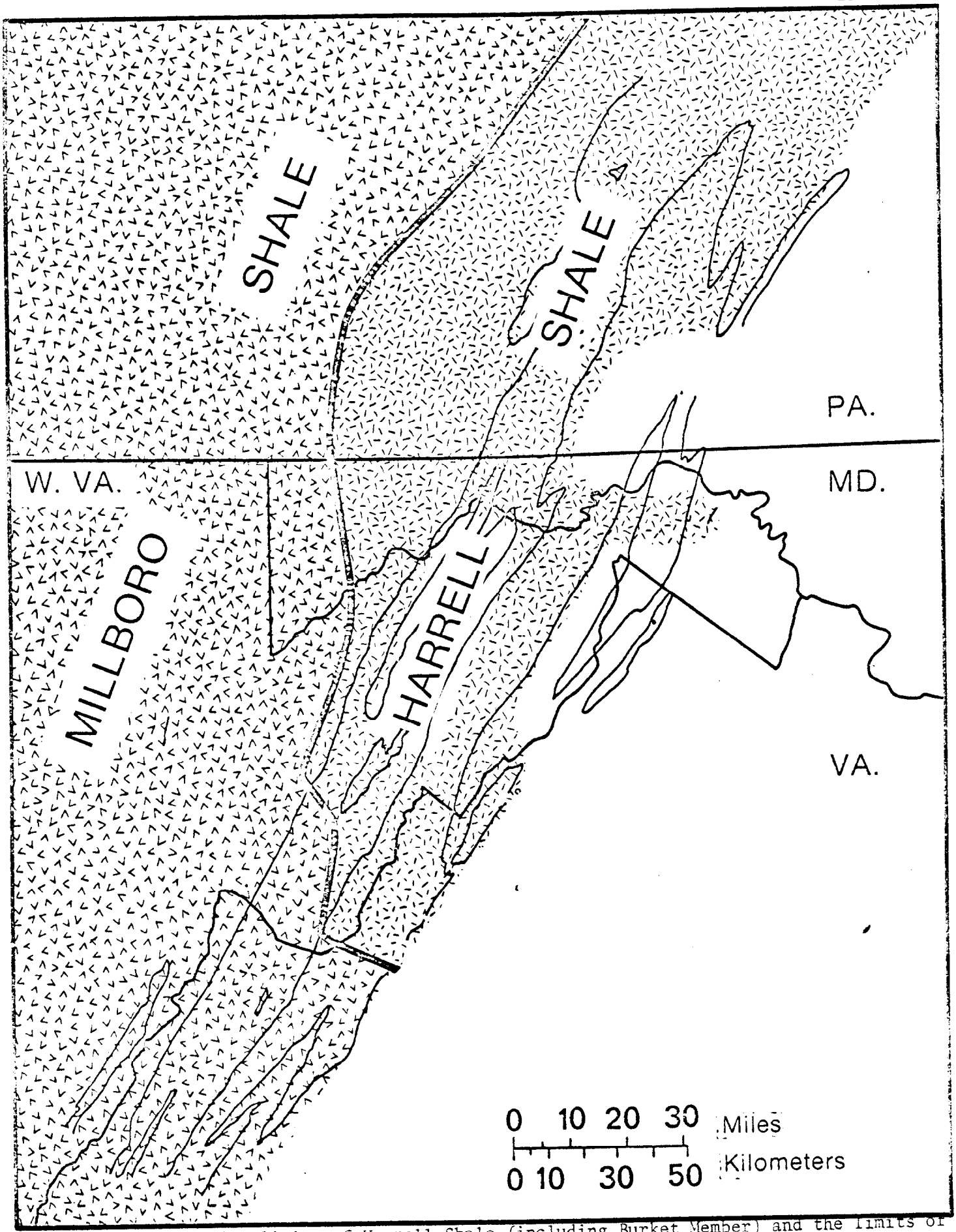

Figure 10. Map showing limits of Harrell Shale (including Burket Member) and the limits of recognition of the Millboro Shale in the project area.

because the Mahantango is coarser in this eastern area and is still a distinct wedge between the Millboro and Harrell. This relationship shows the Harrell Shale to be a northward-extending tongue of the Millboro Shale lithology.

In the northern outcrop area there are three distinct divisions within the Harrell: a basal Burket Member; a middle very dark gray shale portion and an upper zone transitional with the Brallier (see the schematic diagram given earlier).

The contact between the Brallier and Harrell is gradational, and forms a zone averaging about 25 feet thick in the outcrop area (Hasson, 1972). The lowest distinct siltstone is considered the Brallier-Harrell contact. Below this contact the Harrell resembles the Brallier shale, but lacks siltstone. In this zone the Harrell is thickly to thinly laminated, somewhat silty and weathers to olive or light olive gray plates and chips. Silt content in this zone increases upward and the shales become more thickly laminated upward, resembling siltstone, but weathering to very thickly laminated, flaggy plates.

Below the transitional zone and above the Burket Member, the main mass of Harrell Shale is very dark gray, thinly to thickly laminated shale which weathers to yellowish gray plates and sheets. As noted earlier, the formation changes facies eastward and is no longer a mappable unit in the vicinity of the West Virginia-Virginia border; in this area it contains considerable interbedded siltstone and lacks the Burket black shales.

An unusually thick section of Harrell occurs at Keyser, West Virginia (W19) where it is 386 feet thick (Hasson, 1966). Thickening may be partly

due to sedimentation (the Mahantango, Brallier, Foreknobs and Scherr Formations are thicker near Keyser also), but some of the thickening is due to repetition by minor folding. Some drag folding is exposed in the upper part of the section. In most outcrops the Harrell Shale is not involved in drag folds, which is in marked contrast with most exposures of the Marcellus Shale and its equivalent portions in the Millboro Shale.

There was apparently a minor incursion of the Harrell Shale as far east as Hedgesville and Shanghi in Berkley County, West Virginia (W1,W2). This possible Harrell is noted by Woodward (1943) and by Hahman (1963) and Duncan (1967). Ten feet of Harrell was reported by Martin (1964) in the Great Cacapon Quadrangle, Morgan County, West Virginia (W6). We have verified the presence of Harrell Shale at these outcrops. The extent of this embayment is shown on Figure 10.

Burket Member. In the same paper in which he named the Harrell, Butts (1918) also designated a basal black shale as the Burket Member of the Harrell Formation. The named was taken from Burket, an Altoona suburb, which has since been engulfed by the city and no longer exists as a named entity. A description of the type Burket, courtesy of Wallace deWitt, is given in Appendix A. At Horrell Station, Blair County, Pennsylvania (P22), the Burket is about 83 feet of grayish black, platy-weathering, thinly laminated shale resting on the Tully Limestone. Where the Tully is absent or higher in the black shale, the Burket rests on the Mahantango.

The Tully Limestone has been identified (Dennison and Naegele, 1963; Hasson, 1966) as occurring within the Harrell Shale in western outcrops of West Virginia and Maryland. The pre-Tully Harrell Shale (Burket) is

about 80 feet (27m) thick in western exposures, but thins eastward and becomes totally replaced by Mahantango silty shale. At the type Harrell locality the Burket is all post-Tully; there, pre-Tully strata are assigned to the Mahantango Formation. The Burket is all post-Tully in the Altoona region southward to the general vicinity of Bedford, Bedford County, Pennsylvania (P17) where there are a few feet of black Burket shale immediately below the Tully.

In western outcrops we use the name Burket for black, fissile shale either directly above or below the Tully Limestone or concretions. We have not been able to recognize effectively the Burket in wells west of Allegheny Front, so we separate the Burket Member only in the area in which the Harrell crops out.

The Burket is a three-dimensional volume of black shale that encloses the eastern Tully concretions, but is physically continuous above and below as well as between them. Figure 11 shows the areal extent of pre and post-Tully Burket as well as the area in which we can recognize the Burket as a distinct member. The embayments are coincident with the general outline of Perry Bay (Willard, 1935c, 1939) and Grant Bay (Dennison 1970). Apparently the post-Tully Burket grades eastward into the main mass of the lighter-colored Harrell; Butts (1945) earlier noted that the Burket and Harrell alternate east of Tussey Mountain and these units cannot be separated in that area. We note this relationship in several outcrops, as shown in the detailed stratigraphic cross sections. Southwestward along strike the Burket descends beneath the Tully concretions, bed or Member and its base rests almost down on the Clearville siltstone horizon or the immediately overlying few feet of limestone or calcitic shale of

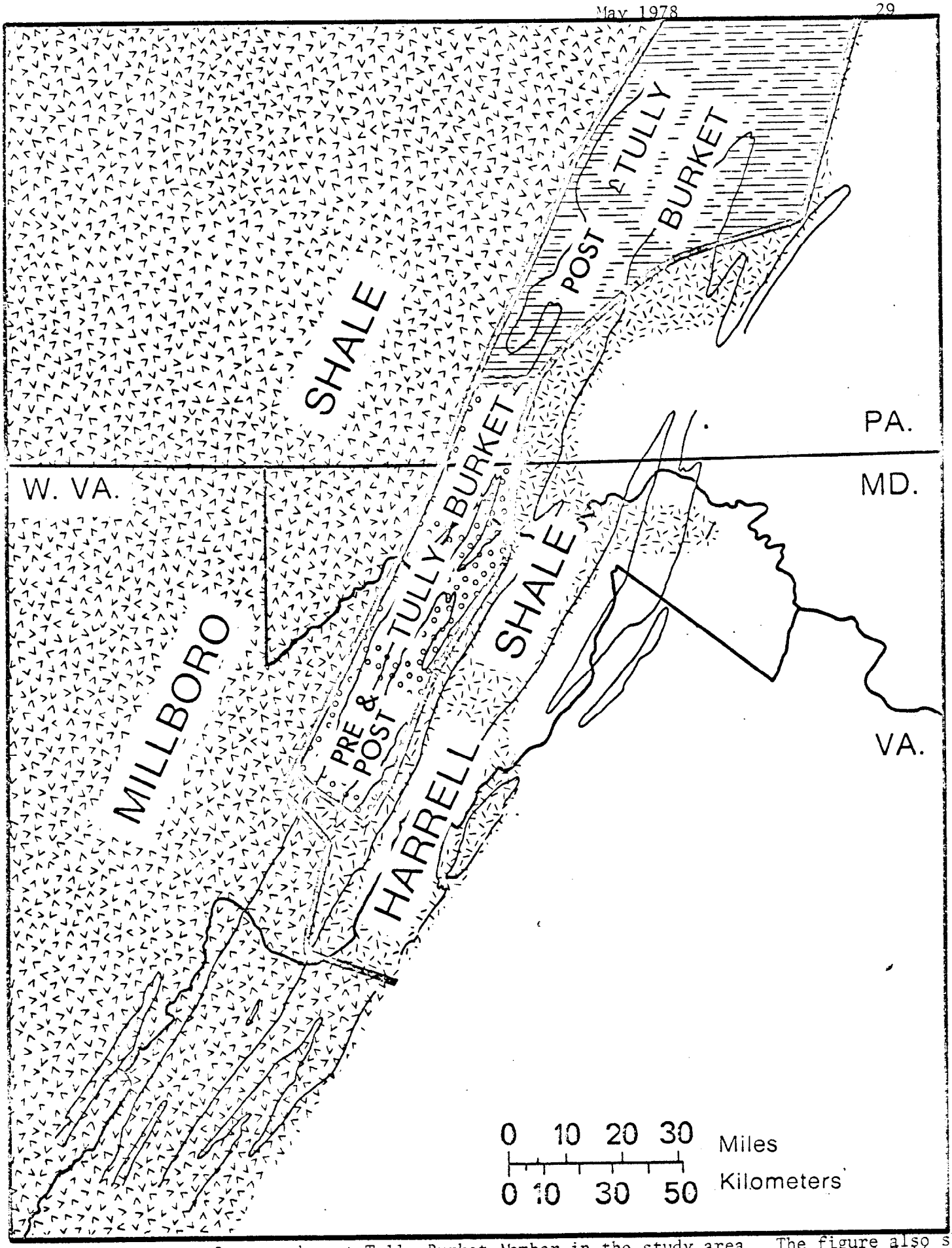

Figure 11. Extent of pre and post-Tully Burket Member in the study area. The figure also shows the eastern and western limits of the Harrell Shale and outlines the axis of the Fulton Lobe.

the Pokejoy Member (Hasson and Dennison, 1974) of the Mahantango Formation. The Burket also passes into the mass of the Millboro Shale and is not recognizable as a separate unit south of the Hopeville Gap North section, West Virginia (W35).

The Burket deforms more easily than the upper gray part of the Harrell. Faulting within the Harrell, where it can be demonstrated, is limited to the Burket, except at LaVale, Maryland (M12) where the upper part of the Harrell is also cut by a fairly large fault (deWitt and Dennison, 1972, guidebook map on p. 21).

Tully Limestone

The Tully Limestone (Vaunexum, 1839) of New York is perhaps the most intensely studied limestone in the history of geology, having been the subject of at least four dissertations in recent years as well as the subject of several earlier reports. Most recently the New York Tully has been monographed by Heckel (1973). The first report of Tully Limestone in the project area, or Pennsylvania for that matter, was by Butts (1918) who identified one foot of limestone containing Chonetes aurora beneath the Burket Shale at Horrell Station, Pennsylvania as Tully. Chonetes aurora is considered a Tully guide fossil. A more thoroughly documented Tully occurence in Pennsylvania was described by Willard (1934) who later expanded the number of known Tully localities in Pennsylvania (Willard, 1935). In Pennsylvania the Tully is a mappable unit from Bedford, northeastward along the Front (Heckel, 1969). To the east and southeast in the project area the Tully is a concretion zone within the Harrell.

Lack of exposures creates a gap of some thirty miles southwestward between Bedford and the Maryland border, so one cannot trace in detail

the decent of the base of the black shale of the Burket to a position well below the Tully concretion zone. Possible Tully within the Harrell Shale was first reported by Dennison and Naegele (1963), who described three such limestone occurrences within the shale. These were at their O'Neil Gap, Route 50 and Corriganville localities.

Hasson (1966) reported more of these calcitic beds in his study of the Harrell along the Allegheny Front. The calcitic horizon was not detected in only three outcrops between Corriganville, Maryland and Elk Lick Run, Grant County, West Virginia. At two of these localities the Tully position is cut out by faulting and in the other (Keyser, West Virginia) it may be covered or leached, since it is present one mile away at McCoole (M15) and 4 miles away at O'Neil Gap (W17).

In subsequent field work we have found more limestones or nodules within the Harrell at approximately the Tully position. Plotting these occurrences on a map shows that the distribution of the limestones closely parallels the pinchout of the Burket Shale Member. The pinchout of the Tully and Burket in effect outlines the southern margin of Perry Bay and the northern edge of the Fulton Lobe at the time of the Taghanic onlap. The general distribution of bedded Tully and Tully concretions in the project area are shown in Figure 12. The outline of Perry Bay and the Fulton Lobe are obvious on the map.

In Pennsylvania the Tully occurrences within the Harrell are at Peru Mills, Juniata County (P1); Huntingdon, Huntingdon County (P5); Eichelbergertown, Bedford County (P16). Bedded Tully occurs at Horrell Station, Blair County (P21), but one must dig to find it because of weathering. Hasson recovered limestone containing Chonetes aurora at the Tully

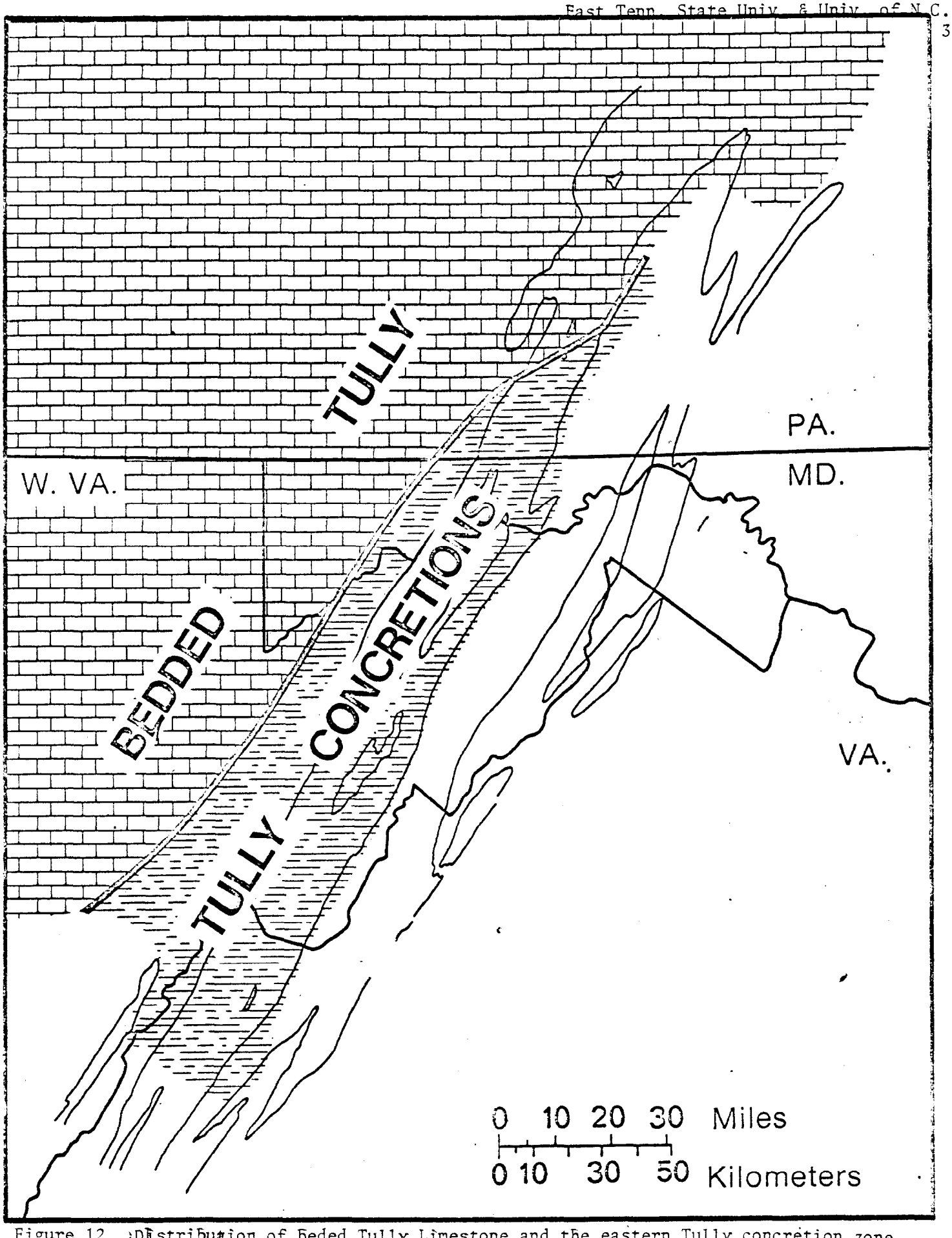

Figure 12. Distribution of Beded Tully Limestone and the eastern Tully concretion zone. The Fulton Lobe is outlined by the eastern Tully embayments.

position at Horrell Station in 1965 and is satisfied that this is the same unit described by Butts (1918). Other occurrences in Blair County are at Newry (P20) and Klahr (P19). In Bedford County the Tully is exposed at Bedford (P17) and Imler (P18).

In Maryland a possible Tully bed or concretion zone occurs at Wolfe Mill, Allegheny County (M10), and at Corriganville (M11), Dawson (M14), and McCoole (M15).

In addition to those Tully occurrences along Allegheny Front, Tully has been observed at Burlington, Mineral County (W14) as a single nodule in the shale. In Grant County there are occurrences at Landes (W32); Fisher (W30) and Petersburg (W33). The Tully is 12 feet thick at Landes. Possible Tully also is present in the section at Frost, Pocohontas County (W49).

In Virginia Tully occurs in the Bullpasture Mountain section (V11) and as large concretions up to 2.5 feet in diameter at the Route 250 section (V13), both in Highland County. A calcareous zone in the type Millboro (V16) is perhaps assignable to the Tully.

Tully Limestone is about 100 feet below the base of the Brallier Formation at the Harrell-Millboro cutoff boundary. This interval decreases eastward toward the region of the Fulton Lobe. The base of the Brallier drops to about 30 feet (10m) above the Tully at the east limit of Tully concretions. We see clear evidence of a Middle Devonian Fulton Lobe with a Perry Bay on the northeast. Southeastward on the Fulton Lobe the Tully Limestone bed changes to concretions and disappears, with the Harrell Shale disappearing next eastward and turbidite siltstone beds descending lower in the section. This produces the situation where,

in extreme eastern outcrops on the Fulton Lobe, the Brallier siltstones lie directly on the silty olive shales of the Mahantango Formation. The Brallier-Mahantango contact is the best estimate of the Tully stratigraphic position in these extreme eastern outcrops.

Along the Allegheny Front the Tully is very dark gray, thickly laminated to medium bedded calcitic shale with some interbedded shaly limestone, which becomes thinly laminated calcitic shale lacking limestone beds or concretions at some localities. The Tully nodule at Burlington, West Virginia (locality W14) consists of about equal proportions of Styiolina biosparite and Styiolina biomicrite. The Landes, West Virginia (locality W32) material is a Styiolina biosparite with large amounts of other mollusks and brachiopods, indicating deep water marine deposition (D.A. Textoris, personal communication, 1968).

That the Tully position in West Virginia is locally represented by a calcitic shale fits well with the overall concept of Tully sedimentation proposed by Heckel (1969, 1973) in which the Tully is derived from a northward lime mud clastic source with a terrigenous clastic source all along the eastern edge of the Appalachian Basin. He says (Philip Heckel, written communication, 1966), "Going southward the latter [referring to terrigenous clastics] would become relatively much stronger and only a little lime, enough to make a shale calcareous, would have been carried as far south as West Virginia. Most of the Tully in New York is purer than anywhere in Pennsylvania, and in Pennsylvania it gets shalier southward toward West Virginia as well as eastward, as previously recognized by Jones and Cate (1957)."

The calcitic shale beds represent the distal, thin edge of Tully

deposition, with a greater clastic to lime ratio. Deposition of lime occurred in embayments in the Harrell mud, as suggested by the arcuate pattern of Tully occurrences.

Beds of calcitic shale occur in the Millboro Shale at Judy Gap (W46) and Ketterman Knob (W45), West Virginia at the same stratigraphic position as the more northerly occurrences. The Ketterman Knob exposure consists of 9.4 feet of very deeply weathered, yellowish gray, calcitic shale. Weathering is so deep that only the mud matrix remains, with the exception of some argillaceous limestone in the drainage ditch next to the road. The presence of Chonetes aurora indicates that this is a Tully exposure.

At Judy Gap (W46) the Tully consists of grayish black, medium-bedded calcitic shale interbedded with black or grayish black thinly laminated shale. This exposure is lithicly identical to that at Elk Lick Run (W38) and both have a similar fauna: Emanuella, Leiorhyncus, Sanderbergeroceras, Ambocoelia, possible Echinocoelia and Chonetes aurora.

In the subsurface west of the Allegheny Front, the Tully serves as an excellent datum and is probably a time-synchronous unit. However, the Tully of the central outcrop belt may not be all of the same age. In our work we have always considered the Tully to be a chronostratigraphic unit, recognizing that there might possibly be some slight diachroniety along the outcrop belt, but not enough to destroy its general utility as a time surface. It was suggested by Hasson and Liebe (1968) that indeed this is the case. Several of the limestones have been processed for conodonts and the Landes locality has yielded critical ammonoids. The age determinations are inconclusive in our estimation, particularly where

correlation across state lines is concerned. We shall discuss the faunally determined ages in the following paragraphs. The conodont determinations were made by John Huddle of the U. S. Geological Survey.

Conodonts were recovered from several Pennsylvania Tully localities. Four of these localities are definite, mappable Tully; the fifth is the eastern pinchout of the Tully. Definite Tully localities and their ages as determined by the conodont fauna are: Bedford (P17)-probably equivalent to Tully; Newry (P20) and Horrell Station (P21)-lower Tully of New York; Imler (P18)-could be Tully. The last locality is the pinchout at Eichelbergertown (P16); three thin beds there supplied a fauna typical of the Tully Limestone of New York and fall in the Polygnathus varcus zone.

Age determinations made on West Virginia samples are mixed. Judy Gap (W46) is probably equivalent to the Tully; the material from Burlington (W14) is not Tully, but equivalent to the upper part of the Pen Yan Member of the Genesee. The presence of Polygnathus pseudofoliatus suggests a Tully Limestone equivalent for material from the Petersburg (W33) section. However, the determinations on material from Landes (W32) and an isolated limestone occurrence near Fisher (W30), which are 13 miles apart in the same strike belt appear contradictory. The Fisher section represents both the upper and lower Tully; that is, there is no doubt that this is a Tully equivalent.

The Landes collections, on the other hand, are younger than the Tully Limestone according to the conodonts. Furthermore, ammonoids from Landes, identified by M. R. House, also suggest an age slightly younger than Tully. The ammonoids were identified as Epitornoceras peracutum (Hall) and Pharciceras (Pharciceras) cf. galeatum Wedekind (the specimens

of which are in the U. S. National Museum). House concludes (personal communication, 1967): "In Europe Epitornoceras would suggest, by analogy with New York, a horizon slightly above the Tully formation (sic) of New York." The conodonts were recovered, incidentially, from the matrix of the ammonoids, so these determinations are obviously quite consistent. The conodont faunas are listed in the section on paleontology.

However, we question whether it is possible to resolve time so closely by paleontologic methods. For example, the ammonoid zonation of the New York Devonian, particularly at the Tully level, (House, 1962) was made on the basis of one incomplete specimen. The Epitornoceras referred to above is the first solid specimen found in North America. Conodont studies of the Tully in New York, with collections made at the same localities, also produced conflicting results (Mayr, 1966; Davis, 1966). We fail to understand how two exposures so close to each other in the same strike belt, as at Landes (W32) and Fisher (W30), can be of different ages. Wherever possible in our interpretive cross sections we have used the Tully as a datum, which is probably an isochronous surface. Actually, we consider the middle of the Tully, at least in the subsurface, to be the best estimate of a time line. The age differences suggested by the fauna may actually exceed the limits of time resolution by paleontologic means; therefore the slight variation in ages suggested by the paleontologic data should not prevent use of the Tully as a general datum, either in a chronostratigraphic or lithostratigraphic sense.

Mahantango Formation

The Mahantango Formation in the central outcrop belt consists of silty, thickly laminated olive-weathering shale with interbedded

siltstone and some limestone. Typically the shale weathers to chips, lumps, and splinters, although spheroidal weathering is not uncommon. The Mahantango is approximately 600 feet thick in the Keyser area and 100 feet at Scherr (W37). Southwestward along strike it is replaced from the base up by grayish black Marcellus Shale; the southwest terminus of silty shale of the Mahantango defines the cutoff between the Millboro and Mahantango Formations as mapping units. The Mahantango also disappears by facies change to the west, and the westernmost silty unit marks the Mahantango-Millboro cutoff in the subsurface.

The downward stratigraphic succession in the Mahantango is similar to that described for the eastern outcrop belt, except that everything thins to the west and southwest and two limestones are introduced into the section.

Unnamed Shale Member

Beneath the Tully in the area north from Bedford, or beneath the Burket from Bedford southwest along strike, the upper part of the Mahantango consists of olive weathering, silty shale similar to that described for the eastern belt. This olive weathering, silty shale is quite thin in the vicinity of Wolfe Mill (M10) and Corriganville (M11), Maryland; most of the upper part of the shale changes over to grayish black Burket Shale in the outcrop belt along the Allegheny Front.

Pokejoy Member

The Pokejoy Member (Hasson and Dennison, 1974) is a very fossiliferous limestone, calcareous shale or coraline biostromal limestone which occurs just above or on the Clearville siltstone in parts of West Virginia, western Maryland and Pennsylvania. The name was taken from its occurrence

at Pokejoy Run, Mineral County. The type section is described by Hasson (1966) and Hasson and Dennison (1974).

The member has several lithologic aspects, as noted above, but is consistent in its stratigraphic position as a calcareous unit at or near the top of the Clearville. The biostromal aspect of the Pokejoy is of considerable interest. It is well developed at Burlington, West Virginia (W14) and in two exposures at Dawson, Maryland (M14). At Burlington the biostrome is 4.5 feet thick and rests directly on the Clearville. The fauna consists of solitary rugose corals, which are not in growth position and exhibit a definite succession. The sequence of corals is a basal zone dominated by colonial Eridiophyllum which is succeeded by Cystiphylloides and Heliophyllum, with some Favosites present also.

The biostrome at Dawson has been noted earlier by Dennison (1963) and Hasson (1966), with the physical details described by Hasson (1972) and the coral zonation by Hasson and Cocke (1973). The succession of corals at Dawson is the same as at Burlington; however there are two mounds here, about 500 feet apart. One, exposed in the creekbed north of the general store at Dawson is a coralline calcisiltite similar to the exposure at Burlington. The second exposure, next to the general store, has very abundant corals which are in a silty shale matrix. Only four of these mounds are known in outcrop, and they are all located on the southern margin of the Fulton Lobe. If more of these "reefs" are present in the subsurface they may have enough porosity to be reservoir rock.

The areal extent of the Pokejoy Member appears to be limited to the central and western portion of the silty shale or siltstone of the

Clearville member. The most southwestward occurrence of Pokejoy Member is at Hopeville Gap (W35) where the upper limestone is shaly and the lower limestone is a concretion zone resting on the silty shale which is the distal equivalent of the Clearville.

Clearville Siltstone Member

The Clearville siltstone in the central outcrop belt thins southwestward along strike and becomes silty shale between Route 50 (W23) and Scherr (W37). The silty shale persists at the same position as the Clearville until just southwest of Hopeville Gap (W35) where it grades laterally into the grayish black Millboro Shale.

The unnamed shale member and the unnamed siltstone member beneath the Clearville both grade laterally into the Millboro Shale.

Frame Shale Member

The Frame Shale Member is a dark shale tongue projecting into the Mahantango Formation from the black Millboro Shale.

Chaneysville Siltstone Member

The Chaneysville Siltstone pinches out to the southwest and is replaced by silty shale between Keyser and Route 50. To the west it pinches out a few miles west of the Allegheny Front. From Mineral County, West Virginia, northward, the top and bottom boundaries of the Chaneysville Siltstone are indistinct.

Landes Limestone Member

The Landes Limestone was named by Reger (1924) for exposures in a now-abandoned county road at Landes, Grant County, West Virginia. The limestone is a 1.3 foot-thick bed (.39m) in a concretionary zone in a gray silty shale within the Mahantango. Reger believed the limestone

to be at the top of the Mahantango [Hamilton] while Woodward (1943) described the Landes as a continuous limestone about 14 inches thick near, but not at the top, of the Mahantango Formation. Both workers erroneously thought the dark shale above the Landes Limestone was Genesee [Harrell of present usage].

Hasson (1966) measured the section at Landes and found the limestone bed to be some 376 feet below the top of the Mahantango rather than near the top. He gives a description of the section (1966, p. 80-84) which also includes the Tully higher up in the section. This description of the Landes section is reproduced in Appendix A. The Landes type locality is east of Allegheny Front; the Landes is represented in Allegheny Front exposures by a limestone concretion zone in the shales below the Chaneysville and are traceable in the Allegheny Front outcrop belt southward to just southwest of Hopeville Gap.

Gander Run Shale Member

The silty, olive-weathering shale of the Gander Run Member is replaced from the base upward by the grayish black Marcellus shale both along strike and to the west. Along strike the Frame and Gander Run Members merge southwestward because the Chaneysville pinches out and the two shales are not separable without the coarser wedge of the Chaneysville to divide them. Thus the Gander Run ceases to be a distinct member of the Mahantango between Keyser (W19) and Route 50 (W23), and grades into the Marcellus Shale. This relationship is illustrated in cross section K-K'.

This same relationship holds true to the west also. The merging of the Frame and Gander Run occurs in the subsurface a few miles west of

Allegheny Front in the north part of the study area; silty shale persists a few miles further westward from the Allegheny Front, but then changes over to black Millboro Shale.

Marcellus Shale

Along strike the blackish Marcellus shale increases thickness at the expense of the gray silty shale of the Gander Run, replacing that unit from its base upwards. However, where the Mahantango silty shale is no longer present, the Marcellus cannot be recognized as a separate formation and the entire interval becomes appropriately designated the Millboro Shale. This same relationship is true across strike also, and the Marcellus is not separable from the Millboro west of the Mahantango pinchout in the subsurface or in southern outcrop belts.

Purcell Member

The Purcell Member is present within the Marcellus Shale in the central outcrop belt, persisting westward into the subsurface, and occurs in outcrops along Allegheny Front from Keyser (W19) southwestward to Judy Gap (W46). In this interval the Purcell maintains a remarkable parallelism to the Tioga Bentonite, which suggests definitely that the Purcell is an isochronous surface.

WESTERN BELT

The downward stratigraphic sequence in the western belt is much more simple than that of the central or eastern belts, because the Mahantango has disappeared by facies change and the base of Brallier to Tioga interval is occupied by black shale. The sequence in the western belt, which is principally subsurface, is as given below:

Brallier Formation

Millboro Shale

Tully Member

Purcell Member

Tioga Bentonite

Needmore Shale or Huntersville Chert

Oriskany Sandstone

Brallier Formation

The Brallier Formation everywhere overlies the Millboro Shale in both outcrop and subsurface. As in the other belts it consists of shale and siltstone and we have used the lowest recognizable siltstone in well records as the base of the Brallier.

Millboro Shale

The name Millboro Shale was proposed by Butts (1940, p. 309) as a mapping unit in Virginia where he could not recognize and separate the Marcellus-Naples interval of the Romney Formation (Tioga Bentonite to base of Brallier as used here). Butts was careful to specify that the term Millboro was applicable only in areas where the silty shale of the Mahantango (Hamilton in Butts' nomenclature) was absent, and the dark shales could not be subdivided in mapping.

The formation is named for Millboro Springs, Bath County, Virginia (locality V16). In his original description Butts estimated a thickness of 1000 feet and stated that there was no evidence of Hamilton [Mahantango] beds. The type Millboro was measured and described in detail by Hasson (1966); it is somewhat thicker than originally estimated by Butts

and there is evidence of poorly developed intertongues of Mahantango silty strata in the section. In fact, it is possible to recognize the Harrell, Mahantango and Marcellus intervals in the section, but these lithologies are too indistinct to map separately. The section is described in Appendix A.

The best estimate of Millboro thickness is about 1500 feet. The measured stratigraphic interval between the top of the Oriskany and the base of the Brallier is 1925 feet; however, only the lower 55 feet of Needmore shale are exposed and there is an estimated 100 feet of Needmore in this area (Dennison, 1961, Fig. 4). The lithologic sequence in the section precludes tectonic repetion except in the lower 500 feet, which would be lower Marcellus Shale and very subject to drag folding and tectonic wadding. Unfortunately, this critical interval is covered. Kozak (1965) estimated a Millboro Shale thickness of 500 feet in the Millboro Quadrangle.

Lithosomes peculiar to the Mahantango and Harrell occur in the type Millboro, but are too feeble to map separately. Some 400 feet below the Brallier occur 11 feet of thickly bedded, pencil-weathering siltstone overlain by 90 feet of splintery weathering, thickly laminated shale. This in turn is overlain by 100 feet of thickly laminated shale which weathers to light olive gray lumps and chips. The 200 or so feet of strata above this are generally more thinly laminated, gray and contain a Harrell fauna. The Mahantango lithosome is not recognizable directly to the northeast or to the west of Millboro Springs, and this silty influence must change to black shale in a short distance away from Millboro Springs.

The presence of recognizable Mahantango admixture in the Millboro precludes the existence of a post-Mahantango unconformity as indicated by both Butts (1940) and Woodward (1943). They postulated the unconformity to account for about 700 feet of stratigraphic thinning along strike; the thinning is more easily explained by stratigraphic convergence resulting from the Mahantango becoming finer grained and changing over to black shale.

In the subsurface the Millboro is all black shale with no recognizable Mahantango or Harrell influence. It is thicker immediately west of the Allegheny Front and thins westward.

Tully Member

The Tully is considered by us to be a member of the Millboro, since it is a calcareous lithosome in the black shale sequence. In the subsurface the Tully is a bedded limestone and serves as an excellent marker bed for the driller. The extent of the bedded limestone in the project area has been indicated previously in Figure 11.

In outcrop the Tully Member is either nodular limestone as at the Route 250 section (V13) or grayish black, calcitic shale as in the Judy Gap (W46) and Elk Lick Run (W38) sections. Seven feet of calcitic shale or shaly limestone in the type Millboro may be assignable to the Tully Member. Other limestones at the Tully position occur at Bullpasture Mountain, Highland County, Virginia (V11) which is on strike with Millboro Springs and at Frost, Pocohontas County, West Virginia (W43). The former locality has a one foot thick limestone concretion zone overlying 35 feet of shale with limestone concretions. At Frost the interval with Tully influence is 42 feet (13.1m) thick, consisting of dark gray shale

with limestone concretions and septaria at the bottom and top of the interval; both the concretion and septaria zones are about six feet thick.

Purcell Member

The Purcell Member is separated from the Tully by approximately 50 feet (15m) of black shale in the exposures from Pendleton County southward along Allegheny Front in our western belt and extends only a short distance west of the Front in the subsurface. The Purcell is traceable south to Judy Gap and is absent in sections farther south along strike in the outcrops we examined. Dennison has seen Purcell in outcrops farther south in Greenbrier and Monroe Counties, West Virginia. It is present in the type Millboro (V16), the Bullpasture Mountain (V11), and Frost (W48) sections. At Millboro Springs the Purcell is 85 feet (26m) of argillaceous limestone and calcitic shale (Hasson, 1966). At Bullpasture Mountain the Purcell is represented by calcitic shale, limestone and limestone concretions through an interval of 109 feet (32.7m). The Purcell at Frost is 40 feet (12.3m) of shale which may have been calcitic before weathering and contains argillaceous limestone beds up to 0.9 foot (.27m) thick.

Westward in the subsurface the Purcell disappears one or two counties west of the Allegheny Front and it is not present in wells to the west.

Tioga Bentonite

The Tioga is present both in outcrop and subsurface. In the subsurface it thins to about 3 feet (1m) in the western part of the project area (Dennison and Hasson, 1976). The Tioga is present in most exposures along Allegheny Front. It is covered at Millboro Springs, ranges through 62 feet (18.6m) at Bullpasture Mountain and extends through 36 feet

(10.8m) at Frost where the sandy micaceous tuff occurs near the top.

Needmore Shale

The Needmore Shale occurs below the Tioga along Allegheny Front; in wells to the west the shale grades into the Huntersville Chert.

PALEONTOLOGY

The following discussion of Harrell-Millboro paleontology is taken from a thesis by Hasson (1966). The data given here, so far as we know, constitute the only systematic faunal survey ever made on the Harrell.

The black shale fauna of western New York, termed the Naples fauna by Clarke (1898, 1903) for its occurrence near Naples, New York, is characterized by such small and thin-shelled pelecypod genera as Buchiola, Paracardium, Pterochaenia and Lunulicardium. Associated with the pelecypods are abundant Styliolina, some Tentaculites, and occasional cephalopods.

Clarke (1903) recognized elements of the Naples fauna in the shales of Allegheny County, Maryland; Butts (1918, 1945) did not hesitate to refer the Harrell-Burket fauna he found in Blair County, Pennsylvania to the Naples and assigned a Portage age to these shales, as he did to the upper 500 feet of shale in the type Millboro Shale (Butts, 1940).

Clarke (1903) considered the Naples fauna as representative of deep water, noting the thin shells and the association with "bituminous" shales. However, the Harrell was probably not deposited in very deep water although it may have been the deepest water in the Appalachian basin at that time.

With the exception of the Burket Member, the Harrell is not what could be termed a truely black shale, nor is it exceptionally fine-grained. Occasional silty beds and thicker laminae suggest periods of generally more rapid deposition and a proximity to shore closer than one expects in a really deep water environment. Based on these observations we believe the Harrell was deposited in moderately shallow

water (150 to 600 feet) and below effective wave base, although certainly the environment was oxygen deficient.

Bottom currents are evidenced by the preferred orientation of Styliolina in many samples. These tiny fossils not only show a general preferred orientation, but also curve around the relatively larger pelecypods, which suggests a micro-current deflection.

Faint ripplemarks are preserved in the stiff silty shale with slight admixture of Mahantango influence at Millboro Springs. These ripples trend N 15 E; restoration of original strike results in a ripple crestline direction of N 7 E. A slightly northeastward depositional strike is supported by other evidence. Woodward's (1943) isopachous maps of the Harrell and Mahantango indicate a north-northeast trend as do the palinspastic diagrams of Dennison (1961) for the Onesquethaw Stage of West Virginia. Also, the direction of most abrupt Mahantango pinchout in a slightly northwestward direction also suggests an almost north-south depositional strike in the Middle and Late Devonian.

The Harrell fauna is obviously a facies fauna of thin-shelled pelecypods and Styliolina. The fauna reflects a relatively low energy environment; the waters above the bottom were suitable for nektonic goniatites and orthocones. Their presence in almost every fossil collection suggests that they were indigenous to the waters over the bottom mud and not carried in as an exotic element.

The Harrell is sparingly fossiliferous and no specimens were found in many of the outcrops studied. One problem, of course, is that few bedding surfaces are exposed, so search must be made among small, loose fragments. Often the outcrop is so weathered that loose material is

not present.

In this study fossils were collected through measured intervals and a census made of each shale fragment collected. Identifications were made to genus and species and tabulated; identifications were made to class when generic or specific identifications were not possible. The counts were combined for each Harrell lithology and percentage abundances calculated; no further statistical comparisons were made. We feel that in this case the relative abundance of a species is a reasonably accurate representation of the Harrell fauna. The percentages are given beyond the decimal, but this is only for arithmentic purposes so the percentage totals approach 100. Styiolina is generally ubiquitous, and its presence contributes noise to the data. In this paper the percentages of each species ignore Styiolina, but it was included in the original work. The results are summarized in the following series of tables and brief discussions.

Brallier Fauna

A sparse Brallier fauna was found at three localities and is included here for comparison with the Harrell. The fauna is listed in Table 1. As in the previous cases the fauna is dominated by small pelecypods with Pterochaenia fragilis the most abundant species. Styiolina does not appear to be quite as abundant as in the Harrell. Pteridichnites biseriatus has been considered a Brallier guide fossil by Willard (1939) and Woodward (1943), but its relative scarcity in these Brallier collections and its occurrence in the transitional beds of the Harrell would suggest that it is not that reliable a guide fossil of the Brallier.

It does serve to distinguish the Drallier from the Mahantango, however.

Transitional Zone Fauna

The upward change from gray Harrell to the slightly silty to silty olive shale of the Drallier is reflected in the fauna. Although pelecypods are still the most common form, the order of generic abundance is reversed. Pterochaenia fragilis is the most abundant species in this facies, followed by Paracardium doris and Buchiola retrostriata. These data are given in Table 2.

Very Dark Gray Harrell Fauna

In the very dark gray shale portion of the Harrell small pelecypods again dominate the fauna. Table 3 indicates a less abundant fossil population in both actual numbers and localities than the Burket. Both lithic types, however, are similar in their faunal content.

Burket Fauna

The total sample and number of localities indicate that the Burket is more fossiliferous than the upper, lighter-colored portions of the Harrell. The Burket data are shown in Table 4.

From inspection of the table it is obvious that pelecypods dominate the fauna. Slightly over half were unidentifiable except to class. Of the remaining sample, Buchiola retrostriata comprises 21%; Paracardium doris and Pterochaenia fragilis comprise 10 and 15 percent, respectively. Buchiola appears slightly dominant, but there is probably no significance to this. Cephalopods are a small part of the fauna.

Tully Fauna

The most striking aspect of the Tully fauna is the more abundant brachiopod fauna in some sections. With the presence of brachiopods, some of the pelecypods characteristic of the Harrell do not occur. This seems to coincide with an environmental change to a carbonate precipitating environment.

An interesting aspect is the occurrence of the bryozoan Palaschara and Tentaculites gracilistriatus in the calcitic shale at Ketterman Knob. Tentaculites does not occur on the same slabs as Ambocoelia, suggesting the two are incompatable; however, Tentaculites does appear to be associated always with Palaschara. The Tully macrofauna is listed in Table 5.

The Tully Member has also produced a conodont fauna which is listed in Table 6. The identifications were made by the late John Huddle of the U. S. Geological Survey. The faunal list for each sampled Tully locality is given along with Huddle's comments and rationale for his decisions.

Millboro Fauna

The fauna of the Millboro is similar to that listed for the Harrell Shale, with the exception of the brachiopod Schizobolus concentricus, which occurred in the Ketterman Knob section (W45) above the Tully. This is not an unexpected genus, since it ranges through the Devonian and is present in both the Marcellus and Naples intervals of the Millboro (Butts, 1940). The observed Millboro fauna is listed in Table 7.

TABLE 1

FAUNA OF THE LOWER BRALLIER

Species	Total	% of Total Pelecypods	% of Fauna
McCoole, Md. (M15)			
Pterochaenia fragilis	54	83.0	60.0
Buchiola retrostriata	11	16.9	12.2
Bactrites	3		3.0
Orthocones	14		15.5
Goniatites	2		2.2
Pteridichnites biseriatus	6		6.6
Ridgeville, W. Va. (W16)			
Pterochaenia fragilis	6	26.0	24.0
Buchiola retrostriata	3	13.0	12.0
Unidentified pelecypods	14	60.8	56.0
Orthoceras filosum	1		4.0
Goniatites	1		4.0
Styliolina fissurella	83		

TABLE 1 (continued)

FAUNA OF THE LOWER BRALLIER

Species	Total	% of Total Pelecypods	% of Fauna
Keyser, W. Va. (W19) (Lower 443 feet)			
Pterochaenia fragilis	104	28.8	28.0
Buchiola retrostriata	74	20.5	19.9
Paracardium doris	43	11.9	11.5
Unidentified pelecypods	139	38.6	37.4
Bactrites	7		1.8
Goniatites	3		0.8
Pelmatozoan columnals	1		0.2
Styliolina fissurella	192		
Keyser, W. Va. (W19) (Lower 50 feet)			
Pterochaenia fragilis	18	30.0	29.0
Buchiola retrostriata	11	18.3	17.7
Paracardium doris	2	3.3	3.2
Unidentified pelecypods	29	48.3	46.7
Bactrites	2		3.2
Styliolina fissurella	83		

TABLE 2

FAUNA OF TRANSITIONAL BEDS

Species	Specimens Per Locality						% of Total Pelecypods	% of Fauna
	W19	W16	W23	W37	W32	Total		
Pelecypoda								
Unidentified	97	25	3	2	9	133	41.4	37.2
Buchiola livonae	3	3				6	1.8	1.6
B. retrostriata	35	3			2	40	12.4	11.2
Paracardium doris	58	6				64	19.9	17.9
Pterochaenia fragilis	24	19	24	8	2	77	23.9	21.5
Lunlulicardium sp.		1?				1	0.3	0.2
Cephalopoda								
Bactrites aciculum	8	1	1			10		2.8
Orthocones	1		2	1	3	7		1.9
Goniatites		1	3		1	5		1.4
Cricoconarida								
Styliolina fissurella	804		23	1		828		
Pelmatozoan columnal	2					2		

TABLE 3

FAUNA OF VERY DARK GRAY HARRELL

Species	Specimens Per Locality W19	W23	W32	P21	Total	% of Total Pelecypods	% of Fauna
Pelecypoda							
Unidentifiable		9	36		45	8.7	8.0
Buchiola livonae?		3			3	0.58	0.5
B. retrostriata	2	10	9	187	208	40.3	37.3
Paracardium doris			6	103	109	21.1	19.5
Pterochaenia fragilis		2	2	143	147	28.5	26.3
Lunlulicardium?			1	2	3	0.58	0.5
Cephalopoda							
Unidentified orthocones			1	7	8		1.4
Bactrites aciculum				14	14		2.5
Goniatites							
Unidentified			2	17	19		3.4
Probeloceras lutheri				1	1		0.17
Cricoconarida							
Styliolina fissurella		11	79	1079	1169		
Pelmatozoan columnal		2			2		

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TABLE 4

BURKET FAUNA

Species	Specimens Per Locality									Total	% of Total Pelecypods	% of Fauna
	W21	W18	W19	W21	W16	W23	W24	W37	W32			
Pelecypoda												
Unidentifiable	76	68		76	31	84	94	2	389	820	51.3	48.6
Buchiola conversa									11	11	0.6	0.6
B. retrostriata	3	36		88		28	42		146	343	21.4	20.3
Paracardium doris	27	12	1	10		14	2		106	172	10.7	10.2
P. delacatum		1								1	0.062	0.05
Pterochaenia fragilis	1	2		2	1	15	170	8	42	241	15.0	14.3
Cephalopoda												
Unidentified orthocones				2			1	1	13	17		1.0
Bactrites aciculum	1	3		12		5	1		28	50		2.9
Orthoceras filosum				1						1		0.05
Goniatites		2		2		17	1		9	31		1.8
Probeloceras lutheri	3									3		0.1
Cricoconarida												
Styliolina fissurella	633	520		1097	138	1185	324		1519	5416		
Pelmatozoan columnal	1									1		

TABLE 5

MACROFOSSILS OF TULLY MEMBER

Species	Locality						
	M14	W21	W23	W30	W32	W45	W46
Pelecypoda							
Buchiola retrostriata	X	X	X	X	X	?	
B. halli				X			
Paracardium doris	X	X	X		X		
P. delacatum		X					
Nuculoidea corbuliformis				X			
Pterochaenia fragilis		X	X				
Paleoneilo constricta				X			
Actinopterina boydi						X	
Brachiopoda							
Ambocoelia umbonata				?	?	X	
Chonetes aurora						X	
Chonetes sp.						X	
Echinocoelia						?	
Leiorhyncus sp.				?			X
Emanuella sp.				X			?
Productoidea indet.						X	
Orbiculoidea sp.						X	
Cephalopoda							
Ammonoids			X		X		
Pharcicereras amplexum?			X		X		
Goniatites		X			X		
Probeloceras lutheri		X					
Bactrites aciculum?	X	X	X		X		
Orthoceras filosum?		X			X		
Sanderbergeroceras?				X			X
Orthocones				X	X		
Bryozoa							
Palachara sp.						X	
Cricoconarida							
Styliolina fissurella		X	X	X	X	X	
Tentaculites gracilistriatus						X	
Wood fragments				X			

X = present in collection

TABLE 6

TULLY MEMBER CONODONTS

The conodont identifications for the localities discussed previously are listed below. The listings are given complete with Huddle's comments and rationale, and are in the order of discussion in the text.

"As you know most of the specimens in the collections you sent me are broken and many of the fragments are not identifiable. I have made the identifications consistent with my reports 0-73-76 and 0-72-98. In some cases I have been more conservative than the man who originally prepared the lists and in other cases less conservative. In part this depends on the recent experience of the paleontologist making the identification because that affects his ability to recognize small fragments: Here are the results of my restudy:

Bedford, Pa. (Slide No. 4) (Locality P17)	No. specimens
Ozarkodina sp.	1
Polygnathus linguiformis Hinde	3
Polygnathus pseudofoliatus? Wittekindt	6

I did not find a fragment I could identify as Hindeodella. The species identified as P. Pseudofoliatus could be regarded as immature forms of P. Pseudofoliatus or referred to P. xylus. The fauna is probably equivalent to the Tully Limestone.

Newry, Pennsylvania (Locality P20)

Hindeodella sp.	4
Ligondina panderi (Hinde)	3
Prioniodina sp.	1
Polygnathus linguiformis Hinde	12
P. pseudofoliatus Wittekindt	5

Horrell Station, Pennsylvania (Locality P21)

Hindeodella spp.	3
Icriodus aff. I. eslaensis Boogaert	2
Ozarkodina sp.	2
Polygnathus linguiformis Hinde	24
P. varcus sl. Stauffer	4

A coarse ribbed morphotype of P. linguiformis ss. is present in this sample and also occurs frequently in the lower Tully Limestone but ranges up into the Frasnian. It is also present in the collection from Newry, Pa. These two samples probably represent the time equivalent of the Lower Tully of New York

Imler, Pennsylvania (P18) — No. specimens

Polygnathus linguiformis Hinde	5
Prioniodina sp.	1

This sample could be equivalent to the Tully Limestone.

Field no. Tully Ls., Peru Mills, Penna. (Locality P1)

No conodonts recovered.

Field no. 257SF Tully Ls. Eichelbergertown, Pa. (Locality P16)

No conodonts recovered. Few Styliolinas seen in rock.

USGS 9072-SD: Field no. 206SF. Tully Ls., Eichelbergertown, Penna. Intersection of Pa. Hy. 26 and road to state Game Farm, Bedford Co., Penna. Tully Ls., lowest bed of limestone 0.5 ft. thick.

Angulodus sp.	2
Hindeodella sp.	1
Icriodus aff. I. eslaensis Boogaert	1
Lonchodina subsymmetrica Ulrich and Bassler	1
Neoprioniodus sp.	1
Ozarkodina sp.	2
Polygnathus alveolipositicus Orr and Klapper	1
Polygnathus linguiformis Hinde	27
P. varcus? Stauffer	3
Synprioniodina sp.	1

USGS 9073-SD: Field no. Tully Bed No. 2, Eichelberger town, Penna. Same locality. Tully ls., limestone bed 0.2 ft. thick about 2-1/2 ft. above base of Tully ls.

Hindeodella angulus Huddle	2
H. sp.	1
Lonchodina subsymmetric Ulrich and Bassler	2
Neoprioniodus armatus (Hinde)	1
Ozarkodina sp.	1
Polygnathus linguiformis Hinde	16
Polygnathus varcus Stauffer	1
Spathognathodus planus Bischoff and Ziegler	1

USGS 9074-SD: Field no. Bed No. 3, Eichelbergertown, Penna. Same locality; uppermost limestone bed, about 0.3 ft. thick in the Tully Limestone.

Hindeodella fragments	4
Ozarkodina sp.	2
Polygnathus linguiformis Hinde	4

These collections contain the conodont fauna typical of the Tully Limestone in New York and are referred to the Polygnathus varcus-zone of conodont biostratigraphy. Polygnathus alveoliposticus is known to occur in the Tully Limestone, and the basal Antrim and New Albany shale, thought to be equivalent in age.

Wolfe Mill, Maryland (Slide No. 2) (Locality M10)	No. specimens
Icriodus latericrescens Branson and Mehl	11

Icriodus occurs in shallow water deposits and apparently was restricted to near surface in the open ocean. This species occurs in the Tully Limestone, but has a much longer range.

Judy Gap, West Virginia (Slide No. 1) (Locality W46)	
Hindeodella sp.	1
Ozarkodina sp.	1
Polygnathus linguiformis	1

Probably equivalent to the Tully Limestone.

Burlington, West Virginia (Slides No. 10, 11, etc.) (Locality W14)	
Ancyrodella sp.	5
Bryantodus collingatus (Bryant)	4
Hindeodella sp.	1
Icriodus sp.	1
Polygnathus dubius Hinde	2

This sample represents part of the Ancyrodella rotundiloba Zone. The fragments of Ancyrodella could be either A. rotundiloba alata or the younger form A. nodosa Ulrich and Bassler. It is probably equivalent to the upper part of the Penn Yan Member of the Genesee Formation or somewhat younger rocks. It is not equivalent to the Tully Limestone.

Landes, Grant County, West Virginia (Locality W32)	
Angulodus sp.	12
Diplidodella sp.	11
Eantigognathus sp.	1
Hibbardella sp.	6
Hindeodella angulus Huddle	4
H. alternata Ulrich and Bassler	12
H. brevis Branson and Mehl	3
H. compressa Huddle	4
H. elongata Huddle	3

	No. specimens
Icriodus cf. I. eslaensis Boogaert	3
I. sp.	1
Ligonodina sp.	6
Lonchodina sp.	8
Ozarkodina aversa Stauffer	6
O. sp.	10
Polygnathus aff. P. angustipennatus Bischoff and Ziegler	1
Polygnathus dubius Hinde	2
Polygnathus pennatus? Hinde	1
P. varcus Stauffer	13
Synprioniodina sp.	7

Sample labeled quote-Tully Ls.-unquote, Kesner Farm, near Landes, Grant Co., West Virginia. Coll. K. Hasson.

Ancyrodella rotundiloba binodosa Uyeno	1
Angulodus sp.	1
Diplododella sp.	3
Eantigofnathus sp.	1
Hibbardella sp.	1
Hindeodella angulus Huddle	1
H. brevis Branson and Mehl	1
H. elongata Huddle	2
H. sp.	4
Ligonodina sp.	1
Oxarkodina sp.	4
Polygnathus dubius Hinde	4
P. pennatus Hinde	2
P. varcus Stauffer	3
P. sp.	4
Synprioniodina sp.	1

These 2 collections and the 4 slides that you sent me (see 0-74-16) all indicate an age for the samples from Kesner Farm near Landes, West Virginia younger than the Tully Limestone of New York. P. dubius and P. pennatus are not known from the P. varcus Zone and the presence of Ancyrodella rotundiloba binodosa also suggests a post-P. varcus Zone age. Most of the ramiform elements, such as, Hindeodella, Angulodus, Hibbardella, Diolododella, etc. have little age significance. They probably belong to 2 of 3 long ranging mutielement species. Icriodus eslaensis and Polygnathus varcus range up into Ancyrodella rotundiloba Zone (Polygnathus asymmetricus Zone) and therefore do not indicate a Tully age (P. varcus Zone) for the collection. On the other hand P. angustipennatus is known only from older rocks and it is either misidentified or the range is greater than previously known.

Landes, West Virginia (Slides No. 6, 7, 8, 9)	No. specimens
Icriodus species	3
Hindeodelloid fragments	10
Polygnathus dubius Hinde	2
P. pennatus Hinde	1

This fauna is probably not equivalent to the Tully Limestone. The fragments are quite small. The identifications are therefore questionable. If this were a fauna equivalent to the Tully Limestone P. linguiformis should be present. I think it is probably Upper Devonian in age and is equivalent to the Upper Penn Yan or Genundewa Member of the Genesee Formation. The list you sent me must have been based on additional material.

Lower Fisher (Locality W30)

Bryantodus sp.	1
Diplidodella sp.	1
Hibbardella angulata (Hinde)	1
Hindeodella sp.	3
Ligonodina sp.	2
Ozarkodina lata Bischoff and Ziegler	5
Polygnathus alatus Huddle	4
P. linguiformis Hinde (weak ribs)	2
P. linguiformis Hinde (strong ribs)	22
P. aff. P. linguiformis Hinde	1
P. pseudofoliatus Wittekindt	2
P. rhenanus Klapper and Phillip	3
Prioniodina macrodenta (Bryant)	2
Spathognathodus semialternans Wirth	5

This fauna is quite similar to the fauna of the lower part of the Tully Limestone in New York, and I think they correlate.

Upper Fisher (Locality W30)

Hindeodella species	1
Icriodus aff. I. eslaensis Boogaert	1
Ligonodina sp.	1
Lonchodina sp.	2
Ozarkodina lata Bischoff and Ziegler	6
Polygnathus alatus Huddle	4
P. linguiformis Hinde (coarse ribs)	20
P. pseudofoliatus Wittekindt	2
P. tuberculatus Hinde	1
Polygnathus varcus Stauffer	2
Prioniodina macrodenta (Bryant)	2
Spathognathodus semialternans Wirth	7

The presence of P. tuberculatus suggests that this bed represents the time equivalent of the Upper Tully of New York, but the fauna definitely indicates correlation with the Tully Ls.

Petersburg (Locality W33)	No. specimens
Hindeodella sp.	1
Icriodus sp.	1
Polygnathus pseudofoliatus Wittekindt	1
P. sp.	1

There is nothing very diagnostic here but the presence of P. pseudofoliatus suggests that this is a Tully Ls. equivalent."

TABLE 7

MILLBORO SHALE FAUNA

Species	Locality W45	V13	V16
Pelecypoda			
Buchiola retrostriata	X		X
B. halli	X		
Paracardium doris		X	X
P. delacatum?			X
Actinopterina boydi	X		
Paleoneilo sp.	X		
Pterochaenia fragilis	X		X
Gastropoda			
Pleurotomaria	X		
Brachiopoda			
Schizobolus concentricus	X		
Ambocoelia umbonata	X		
Bryozoa			
Palaschara sp.	X		
Cephalopoda			
Orthocones	X	X	X
Orthoceras filosum			X
Goniatites	X	X	X
Cricocononarida			
Styliolina fissurella	X	X	X
Tentaculites sp.	X		
Lycopod plant fragment			X

X = present in collection

DESCRIPTION OF CROSS SECTIONS

The descriptions of cross sections which follow are intended to be a general discussion of the information contained on the section, with specific reference to points of significance in interpretation, and also to those points which cause problems in the interpretation. The location of section lines is shown on the reduced index map included earlier in the report and is reproduced full scale (1:500,000) to accompany the sections. The location of the specific data points used in these sections is given in Appendix B.

SECTION A-A'

This section illustrates the regional east-west stratigraphic relationships in the northern part of the study area. The mass of black shale is not divisible west of the pinchout of the Clearville siltstone, and is considered to be Millboro Shale. East of the pinchout the shale is divisible into the units indicated on the section.

The gray Harrell Shale persists and thins eastward. Recognition of the Burket Member is limited to the outcropping area. The western limit of the Burket is placed slightly west of Allegheny Front; the Burket grades laterally into the gray Harrell to the east. The facies change occurs at Peru Mills (P1). In this area of facies change the Burket is all post-Tully.

The Tully is a bedded limestone in the subsurface and becomes a series of limestone concretions and nodules in the east at a position between the Harrell and Mahantango.

In the Backhaus #1 well (P46) the Brallier rests almost down on the

Tully. This is probably due to poor samples. The next well over (P51) seems to be a normal sequence; however, in the Ralston well (P55) the sample quality is poor (actually powder from air rotary drilling) which produces an excessive post-Tully thickness of Millboro in the log. Comparison with adjacent wells suggests as much as 350 feet (106.7m) of excess shale. This may be due to structural thickening or the poor samples.

In the areas of outcrop the Harrell and Burket are both well exposed at Horrell Station (P21) [see appendix A], but the contact with the Tully is covered. At Huntingdon the Harrell and Burket are both thinned, with the Tully occurring as nodules. At Peru Mills (P1) the lower part of the section is alternate medium dark gray and dark gray shale through 23 feet (7m). The Tully occurs as 0.3 foot thick limestone concretions at the base of the dark shale.

SECTION B-B'

This section is similar to A-A' in that it illustrates the regional relationships of the shale units. In the west the Clearville pinchout is the Harrell-Millboro cutoff and the Burket cutoff is immediately west of the Allegheny Front. The Millboro, including the Tully is about 1000 feet (304.8m) thick in the subsurface. The Harrell thins eastward from a maximum of 345 feet (105m) in the Heidingsfelder well (P26) to 50 feet (15m) at Satillo (P4). The Burket disappears between Eichelbergertown (P16) and Satillo and the Harrell is completely absent in the extreme eastern outcrop at Burnt Cabins (P2), where the Brallier rests directly on the Mahantango.

The Tully is relatively thick in the subsurface (110 feet; 33.5m),

thinning eastward and eventually becoming a nodule zone immediately above the base of the Burket Member.

Most of the data used in this section are consistent with the regional pattern as we interpret it, with the exception of the Houston Star #1 well (P47), the data for which is taken from Cate (1963, FIG. 2). Our interpretation differs significantly from Cate in picking the base of the Brallier. We estimate the Brallier position to be 650 feet (198m) above the Tully and choose the lowest definite siltstone as the base of the Brallier. Cate considered slightly silty calcareous shale to be Brallier. We consider this as Millboro and do not recognize the Harrell in the well as did Cate. The position of the Brallier in the Steiner well (P48) is in general agreement with a northwest thickening of the Millboro.

SECTION C-C'

This section is closer to the axis of the Fulton Lobe and the wedge of coarser Mahantango is much more pronounced than in the two previously described sections. The section illustrates the eastward thickening of the Mahantango wedge, with both upper siltstones (Clearville and the unnamed siltstone) present in some wells. The Chaneysville Member is also present.

The western limit of Mahantango is based on estimates from Dennison and Hasson (1976) and Cate (1963). The Clearville pinches out between the Tract 64 well (P35) and the Schartzer well (M17) in the south and three miles west of the Berkey well (P29) as interpreted from Cate. The pinchout is interpolated between these wells to be eight miles west along the line of section from the Berkey well (P29). The lower unnamed

siltstone is present in both the Henninger and Grove wells (P31 and P32) and in the Morris well (P13). However, there is no outcrop data between these points.

The western cutoff of the Burket is made at the Allegheny Front.

The Harrell thins eastward, intertonguing with the Brallier some 40 feet (12m) above the basal Brallier siltstones at Milk and Water Ridge (P14). These are dark shale streaks in the olive Brallier shales. Between here and the Hill well (P11), the Harrell disappears and is barely recognizable in the well log. Data from this well is not used because of apparent structural complications or logging errors. All the marker beds are present in the well (Clearville, Chaneysville, Purcell), but are not where one would expect. The Clearville is some 375 feet (114m) below its position in adjacent wells and outcrop, for example. Thus we did not use the lower part of the well log.

Further east at Hancock (M2) and Pectenville (M1), Maryland, the Brallier rests directly on the Mahantango and the Harrell is absent.

The Tully is substantially thinner in the wells in this cross section and is absent in some areas. It appears to occur in lenses. In outcrop the Tully is slightly above the base of the Burket Member in the Allegheny Front and Wolfe Mill (M10) sections, which of course makes the Burket both pre- and post-Tully.

SECTION D-C'

This section duplicates at the scale used in this paper a section published previously by us (Dennison and Hasson, 1976) and the reader is referred to that paper for details and discussion.

SECTION E-E'

Two things are apparent in this section, which is more or less perpendicular to structural strike in a line generally parallel to U. S. Route 50. The main mass of the Millboro Shale is split by the coarser Mahantango, and secondly, there is complex eastward intertonguing of the Harrell and Brallier.

Between Claysville (W23) and Keyser (W19) the Clearville siltstone disappears. Northwest of this point the shale is not divisible and is all Millboro. Southeast of this point the Harrell, Burket and Mahantango are all recognizable. The limits of the Burket are shown by the vertical dashed lines.

The Harrell intertongues eastward with the Brallier; eventually changing over to olive Brallier shales, with the base of the Brallier descending lower in the section until the Brallier rests directly on the Mahantango at the southeast limit of the line of section. The intertongues shown in the cross section are not schematic, but are the actual measured positions of lithologic changes.

In the subsurface the Tully is bedded limestone, but consists of calcareous shale or nodules in outcrop. Burlington, West Virginia (W12) is the southeasternmost occurrence of Tully nodules in this section.

SECTION F-F'

In this cross section the Millboro is approximately 1000 feet thick (304m) in the western area. Post-Tully shale thickness in the Harmon well (W60) is abnormally thin (15 feet (4.5m) recorded). This is an obvious error (possible fault) compared on a regional basis, so the position of

the Harrell-Brallier contact as plotted is an estimate based on data from adjacent points.

The Tully is bedded in the subsurface and occurs as concretions in outcrop. The concretionary nature of the Tully in so many outcrops may in part be due to weathering along joints, producing rounded blocks from bedded material. In other cases the Tully is distinct limestone concretions separated by several feet of shale, as at Back Creek, Virginia (V13). The Harrell and Burket cutoff positions are as indicated on the diagram.

Both the Burket and the gray Harrell grade eastward into olive silty shale typical of the upper unnamed shale member of the Mahantango. The upper thirty feet (9.1m) grade into the Brallier. Another obvious feature of this section is the descent of the base of the Brallier eastward as the wedge of Harrell is lost by facies change.

SECTION G-G'

This cross section has some problem areas, particularly in the eastern outcrops which are mostly covered and weathered. However, the general eastward thickening of the Millboro is apparent when the Ewing well (W53) and the Whetzel well (V9) as are compared.

Dependable marker beds are present certainly only in the subsurface; the Purcell does not extend westward to the Ewing well. It is quite thin in the Hope Natural Gas #8949 well (W57) and disappears between points W57 and W53.

The Tully is not recognized with certainty in any outcrop section; a 10-foot-thick interval of slightly silty and perhaps once calcareous shale at Mouth of Seneca (W44) is indicated as Tully in the section, but

this is a questionable assignment. The thinning at this locality appears to be sedimentologic; we found no evidence of faulting in the outcrop.

SECTION H-H'

The Millboro thickens markedly eastward in this section. The Purcell disappears to the west between localities W50 and W53. The section is notably thin at Route 250 at Back Creek (V13). There is no evidence of faulting in the section. Dennison measured 228 feet (69.5m) of Millboro here in 1963 and Hasson measured 226 feet (68.9m) in 1965, also noting small limestone nodules at the Tully position; these apparently weathered out, since Dennison could not find them in 1969. However, large limestone concretions were found again by Hasson at this position in 1976. These concretions range up to 2.5 feet (.75m) in diameter and bound an interval of platy to sheety, gray Harrell-type shale. This section is in the same strike belt as Mouth of Sencea (W44) 30 miles (48km) to the north, which is also a thin section when compared to those east and west of it. The thin Millboro in this strike belt is due perhaps to sedimentary convergence or lack of sediment in the area, or the area might possibly have been a high during deposition.

The section at Bullpasture Mountain (V11) is remarkable for two reasons. First, it shows the rapid thickening of the Millboro from 226 feet (68.9m) to 1259 feet (383.8m) in a distance of only 14 miles (23km) along the line of section between Back Creek (V13) and Bullpasture (V11). Secondly, the section contains all the limestones we have identified to the northeast. This is the easiest place in the central Appalachians to observe all five marker carbonate horizons in the Devonian shales: Upper Needmore, Purcell, Landes, Pokejoy, and Tully. This excellent section

is described in detail in Appendix A.

The Tully at locality V11 is 36 feet (11m) of interbedded limestone concretions and shale; the Pokejoy is represented by 24 feet (7.3m) of argillaceous limestone and claystone which is the distal silty influence of the Clearville siltstone. The Landes Limestone is 30 feet (9m) of calcitic shale (7/8) with discontinuous limestone beds 0.3 to 0.7 feet (.2m) thick. The Purcell member is 123 feet (37.5m) thick and consists of calcitic shale (6 feet, 1.8m), interbedded limestone and calcitic shale (8 feet, 2.4m) and 109 feet (33m) of calcitic shale with scattered limestone concretions.

About 5.6 miles (9km) northeast of the Bullpasture section the Bertha Smith #1 well (V10) penetrates the entire Millboro. The Geolog for this well indicates several faults, apparently because the limestones repeat. However, the sequence in the well is a normal one when compared with the outcrop at Bullpasture and there is no significant faulting. However, the section does thicken rapidly between these two localities from 1259 feet (384m) to 2140 feet (652m). Thickness is due in part to the dip of the beds. This is a good example of the value of detailed outcrop control in the interpretation of subsurface data.

SECTION I-I'

This section illustrates a general eastward thickening of the Millboro. Although the elements of other units (Harrell, Mahantango) are faintly recognizable, particularly at Millboro Springs (V16), they are not sufficiently developed as lithosomes to map separately in the outcrop belt.

The Tioga position is in a covered interval at Millboro Springs. The position in the section is assumed to be the same as at Panther Gap (V17) since the two sections are reasonably close to each other (about 5 miles, 8km). Regional studies by Dennison (1961) indicate a thickness for the Needmore Shale of at least 100 feet (30m); since the black shale is quite incompetent, structural thickening in the covered interval should be expected. The thickness of the Millboro in the type section is more likely on the order of 1550 feet (473m) rather than the 1800 (549m) described by Hasson (1966).

The Millboro and Brallier are in fault contact at Panther Gap (V17) with approximately 600 feet (183m) of upper Millboro cut out by the fault. Fortunately, the Purcell provides a dependable common unit with which to tie the two sections together.

SECTION A-J

This north-south section shows a pronounced thickening of the Millboro in the northwest corner of Tucker County, West Virginia; the base of the Brallier (lowest siltstone) is succeeded by 490 feet (149m) of medium dark gray to dark gray shale. We place this in the Millboro because it underlies the lowest logged siltstone and is probably an overly thick transition between the Brallier and Millboro. Of course an alternative interpretation is structural thickening. The remaining 85 feet (26m) of post-Tully shale is typical black shale and definitely belongs in the Millboro.

In the Backhaus #1 well (P46) the Geolog shows siltstone and sandstone down to the top of the Tully. This probably results from cavings

(sample quality is indicated as fair to poor), but comparison with the next well south (Conners #1, P45) suggests thinning of the Millboro. However, samples are powdery in this well and it is difficult to make a pick. The base of the Brallier is placed some 15 feet (4.5m) above the Tully and should be probably higher. In the Gordon #1 well (P44) it is possible to pick Brallier-Millboro intertongues as shown in the cross section.

In the subsurface the Tully is bedded limestone, but in outcrop it appears as limestone concretions interbedded with shale, as at Frost, West Virginia (W48). The concretionary appearance maybe due to weathering along joints, which would produce rounded, concretion-like structures from bedded limestone.

The Purcell is present in outcrop (W48, V14) and in the subsurface (W50). It does not show distinctly in W55, but may be present where logged as a thick calcareous shale. The projected Purcell position is dashed through this calcareous interval which is logged as almost 200 feet (61m) thick. The Purcell is absent northward.

SECTION K-K'

This is a complicated section because it crosses the westward distal margin of the Mahantango both in outcrop and subsurface; it illustrates the nomenclatural and lithic complexities which arise under these conditions. In the northern part of the section the shale sequence can be considered as Millboro. However, between the Beck #2 well (P50) and immediately south of Brushy Run (W42), the siltstones in the upper part of the Mahantango are present. They divide the Devonian dark shale into

the Harrell Shale above and the Marcellus Shale below. As these siltstones are replaced southward by silty shale and eventually by black shale the interval becomes Millboro again.

The northern limit of Harrell is placed at the limit of Clearville; the strata below this tongue of Clearville are considered to be Marcellus Shale and pre-Tully, the strata above it are considered to be Harrell. By definition the Millboro Shale begins immediately north of the Clearville pinchout. The base of the Mahantango descends to the south, coincident with the base of the siltstone. The lower siltstone is probably continuous between wells, but could not be identified on the logs and is shown as separate lenses. The massive siltstones thin on outcrop and change over to olive silty shale which then becomes black Marcellus Shale.

Amsden (1954) recognized Burket in the Robeson well (M16) in Garrett County, Maryland but the Burket is not recognized by us west of Allegheny Front and we arbitrarily cut it off in the subsurface. This cutoff position corresponds closely to that in other sections.

The Tully Limestone is not present continuously. Where the Tully is absent the Burket or Harrell rests paraconformably on the Mahantango. In outcrop along Allegheny Front the Tully is within the Burket black shale rather than at the base of it in this stratigraphic section as in the type area of the Harrell and Burket. At Bullpasture Mountain and Millboro Springs (V11, V16) the Tully is represented by a zone of limestone concretions interbedded with shale. The presence of Tully cannot be demonstrated at Brushy Run (W42).

The Landes concretion zone is present in outcrop, but absent in the

subsurface. The Purcell occurs in most of the sections, but is absent north of the Beck #2 well (P50). Its presence cannot be demonstrated at all outcrops, because our measurements do not go that far down in the section.

The Millboro Shale is approximately 1450 feet (442 m) thick in the northwest at locality (P55) and approximately 1550 feet (472m) at Millboro Springs (V16).

SECTION L-K'

This cross section from Corriganville, Maryland (M10) to U. S. Route 250 at Back Creek in Highland County, Virginia (V13) is reproduced at present scale from previous illustrations (Dennison and Hasson, 1977, in press; Hasson and Dennison, 1978, in press), and we will not elaborate on the discussion here. For this paper, however, we have extended the line of section northeastward to the type Harrell Shale (P21) and southwestward to Mountain Grove (V14).

At the type Harrell the Burket and Harrell Shale are distinct units; as is apparent from the section they begin to intertongue to the southwest along strike. Associated with this is the change in position of the Tully relative to the Burket. In the type area the Tully underlies the Burket; southwestward the base of the Burket descends beneath the Tully, and in Maryland the Tully is well up within the black shale. Structural complications prevent direct tracing into the section at Corriganville.

SECTION A'-I'

This cross section is the easternmost in the project area and it

illustrates several interesting aspects of the stratigraphy. Between Peru Mills (P1) and Burnt Cabins (P2), the Harrell and Burket disappear by facies change into olive shales of the Brallier Formation. The Harrell and Burket in this area were deposited in the southern part of Perry Bay (Willard, 1939) marginal to the northern edge of the Fulton Lobe. South of this point the Brallier rests directly on the Mahantango.

Between Hedgesville (W1), Shanghi (W2) and Gainsboro (V2) there occurs a thin lens of dark shale which may be Harrell. This occurrence is mentioned by Woodward (1943) and in theses by Hahman (1963) and Duncan (1967). The shale in this interval is not unequivocally Harrell and is certainly not mappable as such, but is somewhat darker than the Mahantango or Brallier shales and probably represents what we would term "Harrell influence", that is, a combination of Harrell and Mahantango lithic characteristics so that no distinct lithosome is recognizable. This lens is probably a very narrow embayment in the general area of the Fulton Lobe during the time of distinct Harrell deposition farther west.

About 160 feet (49m) of Millboro Shale are present in the Liberty Furnace (V6) exposure. The lower 67 feet (20m) are medium dark gray shales grading upward through 90 feet (27m) of more Brallier-like (that is, olive) shales to the lowest definite siltstone. The upper part of the Mahantango is also exposed here.

The Kipps Gap (V7) exposure consists of an estimated 321 feet (98m) of medium dark gray shale. The section is overturned and faulted, and the shale is mashed and sheared. At Tunis (V8) only the upper part of the section is exposed, and it consists of medium dark gray shale. The Panther Gap section (V17) is faulted at the top with an estimated 600

feet (183m) of upper Millboro Shale absent because of the fault. The lower part of the section is covered, but the Tioga Bentonite is present and provides a base for the section and the Purcell provides an additional marker bed. The shales are typically grayish black, thinly laminated, and weather to plates and sheets.

SUMMARY AND CONCLUSIONS

This paper has summarized the regional stratigraphic relationships of the Devonian shale sequence over approximately 15,000 square miles in parts of Pennsylvania, Maryland, West Virginia and Virginia from both outcrop and subsurface data. The principal synthesis is contained in the series of stratigraphic cross sections.

The clastic distributary termed the Fulton Lobe by Willard (1939) is centered around Fulton County, Pennsylvania. On the north the Fulton Lobe is bounded by Perry Bay, which is detectable as an eastern embayment of Harrell and Burket Shales, with associated Tully Limestone. On the south it is bounded by Grant Bay (named for Grant County, West Virginia), which is also represented by a shale embayment. Near the center of the lobe, in the area of the Potomac River in eastern outcrop belts, the Brallier rests directly on the Mahantango Formation and the intervening black shale is absent. The Brallier-Mahantango boundary is at the approximate position of the Tully.

The wedge of silty Mahantango strata splits the main mass of Millboro Shale and creates both stratigraphic and nomenclatural problems. We place the west limit of the Mahantango as the limit of Clearville siltstone; west of this line the shales are all Millboro. East of this line the silty strata divides the Millboro into the Harrell and Burket above and the Marcellus below. The Burket Member of the Harrell is recognized only in outcrop; we cannot detect it in well logs and arbitrarily place its western limit at Allegheny Front. To the east the Burket intertongues with the gray Harrell and this formation in turn grades into the basal Brallier.

The black Burket Member results from deposition in deeper, more reducing water during the initial phase of the sea level rise associated with the Taghanic onlap. The onlap drove the shoreline eastward, creating embayments on the north and south margins of the Fulton Lobe. Limestone (Tully) was deposited along with the shale during the maximum phase of the transgression.

There are several excellent marker beds within the Mahantango. The Pokejoy, the Clearville siltstone and the Chaneysville Siltstone. These siltstones and associated silty shales thin and disappear across strike and southwest along strike. The thinning is by stratigraphic convergence rather than by unconformity. The absence of unconformities is demonstrated by the converging intervals between the marker beds. The base of the Mahantango becomes progressively younger to the northwest and southwest as the silty shales are replaced by black shale of the Marcellus Formation.

Several zones in the project area are thought to represent good approximations of time surfaces: the Tully Limestone, the Pokejoy Member, the Clearville siltstone, the unnamed siltstone below the Clearville, the Landes Limestone and its correlative concretion zone, the Purcell member, the Tioga Bentonite, and the base of the Brallier in the Allegheny Front outcrop belt.

The stratigraphic convergence associated with the facies change from silty Mahantango strata to black, fissile shale results from the transition from fairly shallow prodelta deposition into deeper water distal prodelta black muds. The depositional slope was relatively gentle so the Mahantango generally lacks turbity current deposits. This contrasts

markedly with the typical turbidite origin of the Brallier siltstones.

The southwestward thinning, which is apparent in the sections along structural strike, is an apparent, rather than actual maximum rate of thinning because the sections are oblique to the original sedimentary strike. True depositional strike is approximately in a north south direction. The maximum rate of thinning off the Fulton Lobe is shown in our Mason-Dixon cross section (Dennison and Hasson, 1976) which is reproduced in this report as Section D-C' and Figure 6.

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APPENDIX A

SELECTED MEASURED SECTIONS

The type sections described in this appendix are taken from a thesis by Hasson (1966) except the description of the type Burket, which was provided by Wallace deWitt. The described sections were measured by us in the summer of 1965; the Harrell Shale section was remeasured in August 1966; the type Millboro has been revisited several times since the original description was made. The type Harrell was measured by tape; the type Landes and Millboro were planetabled and the details filled in by tape and ruler. The section at Bullpasture Mountain contains all the limestone marker beds described in the text.

Type Section of Harrell Shale

Locality P21, 40°27'N, 78°17'W, Horrell Station, Blair County, Pennsylvania. Section measured along dirt road on northwest side of Pennsylvania Railroad tracks. The section is 4.2 road miles southeast along an unnumbered county road from its intersection with U.S. Route 22 at Geesytown. This is the type section of the Harrell Shale described by Butts, 1918. The lower part of the Burket Member is fairly well exposed, but the contact with the Harrell is now covered. A thickness of 83 feet is assigned to the Burket. Total thickness of the Harrell and Burket is 262 feet, differing somewhat from Butt's (1918) figure of 250 feet. This difference can be accounted for by choice of dip average. The upper part of the section appears to be faulted. A shear zone was observed with dips of 60° above and 30° below, probably with little stratigraphic displacement.

		Feet
15.	Brallier Formation. Not measured. The contact with the Harrell is covered, but blocky-weathering siltstone is present in float. The amount of siltstone increases markedly above this point, thus the contact is estimated correct within 3 feet.	

		Feet
	Harrell Shale (262 feet)	
	Transitional beds (24.6 feet)	
14.	Shale, silty, weathers light olive gray, chippy to platy. A few thickly laminated, very silty beds present.	14.0
13.	Shale, very silty, almost siltstone but retains shaly parting, weathers light olive gray.	0.5
12.	Shale, silty in part, mostly thickly laminated; weathers light olive gray, platy to chippy.	6.0
11.	Shale, very silty, almost siltstone.	0.1
10.	Shale, mostly thickly laminated; weathers light olive gray, platy with some chippy; plates are stiff but not silty. This is the lowest transitional bed.	4.0
9.	Shale, thinly laminated, probably dark gray when fresh, weathers into large yellowish gray and light olive gray plates; some weather with distict brownish tinge; brownish shale is thinly laminated paper shale.	78.0
8.	Shale, dark gray, mostly thinly laminated with some thickly laminated, weathers platy and yellowish gray, some with brownish tinge.	74.0
	Burket Member (83 feet)	
7.	Covered. The top of the covered interval is considered to be the contact between the gray Harrell and the grayish black Burket Member. The thickness for the Burket assigned here is close to that given by Butts (1918, p. 524).	30.0
6.	Shale, grayish black, thinly laminated; limestone nodule .3 x .7 feet at base of interval.	8.0
5.	Shale, grayish black, thinly laminated with some thickly laminated; weathers platy; not silty, but plates ring slightly when tapped.	14.0
4.	Shale, grayish black, limonite-stained, slightly silty, thinly to thickly laminated; weathers to yellowish gray splinters with some small plates and chips. Slight tendency to spheroidal weathering.	12.0
3.	Shale, very slightly silty, grayish black, thinly laminated; weathers platy and medium dark gray. Poorly exposed.	19.0
	Tully Limestone (2 ? feet)	
2.	Limestone, argillaceous, medium dark gray, fossiliferous; weathers to nodules. Chonetes aurora. Very deeply weathered. Thickness estimated.	2.0
	Mahantango Formation	
1.	Shale, silty, thickly laminated; weathers light olive gray and lumpy. Not measured.	

Type Section of Burket Member of Harrell Shale

Locality P22, 78°26'W, 40°29'10"N. This description of the type Burket is provided through the courtesy of Wallace deWitt, Jr. of the U. S. Geological Survey. The description has been changed to conform to the format of the other sections described in this Appendix.

Type section of the Burket Member of the Harrell Formation at Burket, Altoona, Blair County, Pennsylvania. The section is located at Endress School in Burket (now a part of South Altoona) and along the road to Burgoon Run west of Endress School, Logan Township, Blair County, Pennsylvania. (78°26'W, 40°29'10"N)

The section was measured on 4/16/58 by W. deWitt, Jr., and George W. Colton. Plane table section corrected for dip. Beds dipping to west at 60° to 65°. Base of section in vacant lot across the street (south) of Endress School.

		Feet
	Brallier Formation. The basal 210 feet measured. Total thickness not determined.	
27.	N5 to 5Y 5/1 medium-gray to medium olive-gray silty shale and silt-shale with 10 to 15% of resistant discrete siltstones from 0.1' to 0.3' in the upper 20 feet of the unit. A scattering of thinner siltstones in the lower part of the unit. 0.5' siltstone 17.8' below the top of the unit. Top of exposed sequence along street west of Endress School.	59.8
26.	5Gy 5/1 soft greenish-gray fissile slightly silty shale with some N2.5 to N3 brownish-black to very dark gray shale stringers intercalated.	3.6
25.	N5 to 5Y 6/1 very silty shale and some very shaly siltstone with 15 to 20% resistant discrete laminar-bedded siltstones (turbidite) scattered throughout the interval. Scattered covered intervals of small extent.	59.0
24.	5Y 6.5 to 6/1 resistant ripple-bedded siltstone.	0.6
23.	N6 light gray silty shale parting.	0.15
22.	5Y 6/1 resistant quartzose very coarse-grained siltstone. Base sharp top gradational. First massive Brallier type siltstone in the sequence.	0.75

		Feet
21.	N5 to 5Y 5/1 medium gray to medium olive gray silty shale with about 15% of 0.05' to 0.15' N6 light gray resistant laminar-bedded siltstone.	11.0
20.	5GY 5/1 soft fissile, unfossiliferous medium greenish-gray shale with stringers of N 2.5 to 5Y 2.5/1 dark brownish-gray to very dark gray shale in the lower part of unit.	2.5
19.	5Y 4.5/1 to N5 medium olive gray to medium gray very silty shale and silt-shale with less than 10% discrete beds of siltstone 0.01' to 0.1' thick. Buchiola sparingly present, but locally abundant on some siltstone beds.	37.0
18.	5Y 3/1 medium dark brownish-gray iron-stained shale, soft.	1.0
17.	N5 medium gray very silty shale with 0.1' to 0.15' N6 light gray siltstone in middle 60% of unit. 0.4' siltstone discrete resistant bedded forms center line of unit. Upper and lower 20% of unit largely siltstone free.	26.5
16.	N5 medium-gray very silty shale with abundant 0.01' to 0.05' discrete siltstone laminae in the middle 60% of unit. 0.4' resistant siltstone crops out at the middle of this unit. The upper and lower 20% are largely devoid of siltstone laminae.	5.3
15.	5Y 2 to 2.5/1 soft brownish-black iron-stained shale. Base sharp top gradational into unit above.	1.1
14.	5Y 5/1 very silty medium-gray shale with a 0.2' discrete siltstone at 0.6' and a 0.5' resistant siltstone bed at top of unit.	1.3
13.	5Y 6/1 light gray laminar-bedded, discrete siltstone with a sharply delineated base and a gradational top. (Turbidite ?)	0.2
12.	5YR 2.5/1 brownish-black iron-stained shale.	0.2
11.	N5.5/1 medium light gray discrete resistant quartzose siltstone. The first discrete siltstone in the sequence. We have arbitrarily selected this siltstone bed to mark the base of the Brallier Formation.	0.1
	Harrell Formation: 232 feet thick.	
	Unnamed gray member of the Harrell Formation: 119'	
10.	N5 medium-gray silty shale with scattered 0.05' stringers of N6 quartz silt. A layer of 0.1' x 0.4' calcareous nodules composed mainly of Styliolina fissurella in a silty carbinate matrix occurs in the top of this gray shale unit.	4.8
9.	5YR 2/1 soft brownish-black, iron-stained shale.	1.2

		Feet
8.	Homogeneous sequence of N5 to 5Y 5/1 medium-gray to medium olive-gray silty shale. No discrete beds or stringers of siltstone observed although sequence is well weathered.	34.0
7.	Concealed.	8.0
6.	Essentially continuous outcrops of moderately to slightly silty shale ranging from dark greenish-gray 5GY 3.5/1 at the base to medium olive gray 5Y 5/1 in the upper part. No discrete beds or stringers of siltstone. A "Naples" fauna of small fragile-shelled forms--Buchiola, Paracardium, Pterochaenia, Styliolina, and Bactrites-- locally abundant. The gray Harrell is less fissile and less resistant to erosion than the underlying black shale.	70.0
5.	Transitional sequence of intercalated brownish black shale 5YR 2/1 and 5Y 3/1 to 5GY 3.5/1 dark gray to dark greenish-gray sub-fissile shale. Rock is slightly to moderately silty.	1.0
	Burket Member of the Harrell Formation: 113'	
4.	Homogeneous sequence of N2 to 5YR 2/1 black and brownish-black silty, non-calcareous shale. Weathers to rusty brown iron-stained chips with light gray to white edges.	25.0
3.	Sequence of N1.5 to 5YR 2/1 rusty-weathering brownish black to grayish-black slightly to moderately silty shale. Moderately to poorly exposed along the street west of Endress School. Sequence appears to be all black shale.	74.0
2.	N2 to 5YR 2/1 black to brownish-black fissile, slightly silty shale. Shale chips are commonly stained by iron oxide to shades of red and orange. No nodules observed in sequence. Unit is well exposed in the vacant lot across the street from Endress School and in the low road banks directly in front of the school building.	14.0
	Mahantango Formation: Only upper 12 feet well exposed.	
1.	N4 to 5Y 5/1 medium dark gray to medium olive gray, silty, chunky- to lumpy-weathering massive mudrock. The rock is deeply weathered and stained by iron oxide. 0.15' to 0.3' lenticular beds of very argillaceous "coquinoid" limestone are intercalated at 0.8' to 1.5' intervals. Fossils are abundant in the Mahantango, mainly small forms. The contact of the Mahantango with the overlying Burket Member of the Harrell Formation is sharp. No evidence of the Tully Limestone.	12.0

Remarks:

Since this section was measured, the house has been built on the lot across the street (south of) Endress School, and the contact between the Mahantango Formation and the Burket Member of the Harrell Formation has been covered by the house and surrounding lawn.

Because of the relatively low cuts along the street west of Endress School and the considerable weathering of the Brallier Formation in these cuts, the Brallier may appear somewhat less silty than normal and the number of discrete beds of siltstone less than would be seen in a deep fresh cut. Prolonged weathering of the Brallier tends to reduce the siltstones to beds of silt-shale intercalated in the surrounding silty shale.

The section at and west of Endress School did not appear to be faulted, however, faults of small displacement may be present in the covered intervals or in the poorly exposed parts of the section.

Type Section of the Landes Limestone

Locality W32, 38°52'N, 79°13'W. This is the only measured section of the type Landes. The exposed section extends from near the base of the Mahantango through the Brallier Formation. The Mahantango-Harrell portion is given here. The Tully calcareous zone of the Harrell is well exposed. Almost complete exposures were obtained on the dirt road leading to Gordon Church and on the farm of Mrs. Audrey Kesner, about 1/2 mile south of the Landes Post Office.

		Feet
	Brallier Formation (7.7 + feet)	
59.	Covered.	
58.	Siltstone; weathers blocky and light olive gray.	0.2
57.	Shale, thin to thickly laminated; weathers light olive gray, chippy. Silty in part.	7.0

		Feet
56.	Siltstone; weathers blocky and light olive gray.	0.5
	Harrell Shale (222.5 feet)	
	Transitional beds (32.5 feet)	
55.	Shale, silty, with some very silty shale, thickly to thinly laminated; weathers light olive gray.	2.5
54.	Shale, very silty.	0.2
53.	Shale, as in unit 56.	5.8
52.	Shale, silty, medium dark gray, thinly to thickly laminated; weathers light olive gray, some flaggy with some chippy and platy.	8.0
51.	Covered.	4.0
50.	Shale, medium dark gray, dark gray when fresh, thickly laminated with some thinly laminated; weathers light olive gray and platy.	12.0
49.	Covered.	8.0
48.	Shale, medium dark gray, thin to thickly laminated; weathers light olive gray and platy.	14.0
47.	Covered.	1.0
46.	Shale, medium dark gray to dark gray when fresh, thinly laminated with some thickly laminated; weathers yellowish gray and platy.	12.0
45.	Covered.	40.0
44.	Shale, medium dark gray, seems to be slightly silty in part, thickly with some thinly laminated; weathers light olive gray, platy and chippy.	20.0
43.	Covered.	8.0
42.	Shale, as in unit 45.	15.0
	Burket Member (72 feet including 12 feet of Tully)	
41.	Shale, medium dark gray, dark gray when fresh, thickly to thinly laminated; weathers yellowish gray and platy.	14.0
40.	Shale, medium dark gray, dark gray when fresh, thinly laminated with some thickly laminated; weathers yellowish gray and platy.	17.0
	Tully Interval (12 feet)	
39.	Shale, calcitic, medium gray, thinly laminated; weathers to large plates. Limestone nodules in both lower and upper parts of interval. Nodules are interpreted as weathering out of bed or beds of limestone. Nodules in the lower part are up to 0.3 foot thick and 1.5 feet across. This entire interval is assigned to the Tully.	12.0
38.	Shale, medium dark gray, dark gray or grayish black when fresh, thinly laminated with some thickly laminated; weathers yellowish gray and platy.	22.0

		Feet
37.	Shale, as in unit 39 but with a little more thickly laminated shale.	7.0
	Mahantango Formation (564.5 feet)	
36.	Shale, dark gray, thickly laminated; weathers chippy with tendency to spheroidal weathering. Flattened ellipsoidal limestone concretions up to 0.5 foot in diameter 2 feet above base of this interval (position of Pokejoy Limestone Member).	9.0
35.	Shale, very dark gray, thickly to thinly laminated.	3.0
34.	Shale, grayish black, thinly laminated; weathers platy.	2.0
33.	Shale, dark gray, thickly laminated; weathers platy to almost spheroidal.	1.0
32.	Shale, grayish black, thinly laminated; weathers platy.	5.0
31.	Shale, dark gray, thickly laminated with trace thinly laminated; weathers chippy with slight tendency to spheroidal weathering. Plates or chips ring when hit together.	10.0
30.	Shale, pyritic, grayish black, thinly laminated; weathers to stiff plates and sheets.	50.0
29.	Shale, slightly calcitic, medium dark gray, thickly laminated with ellipsoidal argillaceous limestone concretions up to 0.6 foot in diameter. Concretions not in distinct bed. Thin layers of dark gray shale interbedded at base of this interval.	12.0
28.	Shale, slightly silty and calcitic, medium dark gray with no concretions; weathers medium gray to light olive gray.	8.0
27.	Shale, silty, crumpled, dark gray, a few small concretions less than 0.1 foot at top; weathers yellowish gray, platy and chippy with tendency to spheroidal weathering.	11.0
26.	Shale, stiff and very slightly silty, grayish black, thinly laminated with some thickly laminated; weathers platy with some chips. Rare nodules up to 1 inch in diameter.	16.0
25.	Shale, grayish black, thinly laminated; weathers platy.	80.0
24.	Limestone, argillaceous, nodular, in drag fold.	2.5
23.	Shale, dark gray, thickly laminated, poorly exposed.	7.0
22.	Shale, dark gray, thinly to thickly laminated; weathers to tiny plates and some chips; drag folded.	49.0
21.	Shale, slightly silty, very calcitic; weathers light olive gray. Pelmatozoan columnals.	1.0
20.	Shale as in unit 23.	17.0

		Feet
19.	Shale, grayish black, thinly laminated; weathers yellowish gray, platy and chippy.	45.0
18.	Shale, calcitic, thickly laminated; weathers light olive gray; crinoid stems, Atrypa.	1.4
17.	Shale, grayish black, thinly laminated; weathers platy. Septarian limestone nodule 1.5 x 3.0 feet.	6.6
16.	Shale, dark gray, thinly laminated; weathers platy.	8.0
15.	Covered.	50.0
14.	Shale, slightly silty, thickly laminated, some thinly laminated; weathers light olive gray, lumpy to chippy	17.0
	Landes Limestone Member (1.3 feet)	
13.	Limestone, argillaceous, medium dark gray; weathers moderate yellowish brown. Atrypa spinosa, other brachiopods.	1.3
12.	Shale, slightly silty, possibly calcitic when fresh, dark gray; weathers lumpy; scattered limestone nodules up to 0.3 foot.	17.7
11.	Shale slightly silty, thickly laminated; weathers lumpy and light olive gray; fossiliferous. Limestone concretions up to 0.3 foot scattered through interval, large concretion at top and base of interval.	20.0
10.	Shale, thickly laminated; weathers lumpy.	1.0
9.	Shale, thinly to thinly laminated; weathers light olive gray and chippy with slight tendency to spheroidal weathering; concretions 2 feet in diameter and 1 foot thick occur 9 feet below top of interval and concretions up to 0.2 foot thick occur 10 feet above base of interval.	40.0
8.	Shale, calcitic, fossiliferous; weathers light olive gray; chippy.	1.0
7.	Shale, as in unit 9.	11.0
6.	Shale, thickly laminated, dark gray; weathers chippy; rare small concretions.	34.0
5.	Shale, calcitic, thickly laminated; medium dark gray; weathers chippy.	2.0
4.	Shale, dark gray, thickly laminated; weathers chippy to splintery; concretion 1.0 foot in diameter at base of interval.	15.0
3.	Shale, dark gray, thickly laminated; weathers chippy.	5.0
2.	Shale, dark gray; weathers chippy to platy with slight tendency to spheroidal weathering (Marcellus influence).	5.0
	Marcellus Shale	
1.	Covered.	

Type Section of Millboro Shale

Locality V16, 37°59½'N, 79°38'W. Measurement and description made in cuts along Virginia Route 39 at Millboro Springs, Bath County, Virginia. Thickness calculated from plane table survey and taped details.

		Feet
	Brallier Formation	
60.	Not measured.	
59.	Siltstone; weathers light olive gray.	0.4
58.	Shale, thickly laminated; weathers light olive gray.	2.6
57.	Siltstone; weathers light olive gray.	0.1
56.	Shale, as unit 58.	1.9
55.	Siltstone, weathers blocky and light olive gray.	0.3
	Millboro Shale (1827 feet)	
	Harrell Influence (190 feet)	
	Transitional beds (64 feet)	
54.	Shale, dark gray, thickly laminated; weathers light olive gray, chippy.	64.0
53.	Shale, slightly silty, stiff, dark gray, thinly with some thickly laminated; weathers yellowish gray and platy.	54.0
52.	Shale, stiff, thin to thickly laminated; weathers light olive gray; Brallier-type shales.	16.0
51.	Shale, grayish black, thin to thickly laminated; weathers platy and yellowish gray.	41.0
50.	Shale, calcitic, or limestone, shaly, medium dark gray; exposed in creek bed.	7.0
49.	Shale, as unit 54.	8.0
	Mahantango Influence (757 feet)	
48.	Shale, silty, grayish black, thickly laminated; weathers light olive gray, lumpy and chippy with some splinters.	104.0
47.	Shale, silty, thickly laminated; weathers light olive gray and splintery.	92.0
46.	Siltstone, thickly bedded; weathers to light olive gray "pencils."	11.0
45.	Shale, silty, stiff, grayish black; weathers yellowish gray, platy to sheety. Faint ripple marks trending N 15 E.	28.0
44.	Covered.	25.0
43.	Shale, as unit 48.	66.0
42.	Shale, grayish black, thinly laminated; weathers platy.	261.0
41.	Shale, silty in part, thickly to thinly laminated; weathers light olive gray and chippy. Grades into units above and below. Carbonate concretions (0.4 foot) in basal half.	32.0

		Feet
40.	Shale, stiff, grayish black; weathers platy.	85.0
39.	Shale, thin to thickly laminated; weathers light olive gray, chippy to platy with some splintery; slight tendency to spheroidal weathering on joint faces.	11.0
38.	Siltstone, thickly laminated; weathers light olive gray, chippy to lumpy with some spheroidal weathering; Mahantango lithology.	1.2
37.	Shale, silty in part, thin to thickly laminated; weathers light olive gray, chippy to platy; slight tendency to spheroidal weathering.	6.8
36.	Shale, grayish black, thinly laminated; weathers platy; some plates light olive gray.	6.0
35.	Shale, grayish black, thickly laminated.	2.0
34.	Shale, grayish black, thinly laminated; weathers platy with some chippy.	3.0
33.	Shale, grayish black, thickly laminated; weathers light olive gray, platy to chippy.	2.0
32.	Shale, grayish black, thinly laminated; weathers platy.	15.0
31.	Shale, dark gray, thinly to thickly laminated; weathers light olive gray, platy to chippy.	5.0
30.	Shale, silty, thickly laminated; weathers light olive gray, chippy. Lowest recognizable bed of Mahantango influence.	1.0
	Marcellus Influence (880 feet, with best estimate of total thickness of Marcellus as 600? feet. Thickness of lower Marcellus complicated by probable concealed structure.	
29.	Shale, grayish black, thinly laminated; weathers platy; not as stiff as shale below.	46.0
28.	Shale, grayish black, thinly laminated; weathers platy; not as pyritic or stiff as below.	70.0
27.	Shale, grayish black, thinly laminated; weathers medium dark gray and platy; pyritic and very stiff.	17.0
26.	Shale, grayish black, thinly laminated; weathers medium dark gray and platy; plates are large and somewhat stiff.	19.4
	Purcell Limestone Member (85 feet)	
25.	Limestone, argillaceous, medium dark gray, medium-bedded; weathers light olive gray.	3.6
24.	Shale, dark gray, thinly laminated, noncalcitic; weathers yellowish gray, platy.	7.0
23.	Shale, calcitic, thinly to thickly laminated; weathers platy to chippy .	4.1

		Feet
22.	Limestone, as unit 28.	0.9
21.	Shale, calcitic, thinly to thickly laminated; weathers yellowish gray, chippy to platy.	8.1
20.	Limestone, as unit 25.	0.9
19.	Shale, calcitic, thinly to thickly laminated; weathers yellowish gray, chippy to platy.	9.0
18.	Shale, calcitic; weathers yellowish gray.	5.0
17.	Limestone, argillaceous, medium dark gray, medium-bedded; some shale up to 0.5 foot; prominent fracture cleavage dips 65°; limestone containing fibroradiating concretions; tends to spheroidal weathering.	13.0
16.	Shale, calcitic, thinly laminated; weathers yellowish gray, platy.	7.0
15.	Limestone, shaly; weathers yellowish gray.	2.5
14.	Shale, calcitic, thinly laminated; weathers yellowish gray and platy.	19.9
13.	Limestone, argillaceous, medium dark gray; base of Purcell Limestone Member.	0.6
12.	Covered	5.0
11.	Shale, thinly to thickly laminated; weathers yellowish gray, platy to chippy.	3.0
10.	Shale, grayish black, thinly laminated; weathers yellowish gray, platy	23.0
9.	Shale, dark gray, thinly laminated; weathers yellowish gray, platy or in large sheets	18.0
8.	Shale, grayish black, thinly laminated; weathers yellowish gray, platy with some chippy.	66.0
7.	Covered.	18.0
6.	Shale, grayish black, thinly to thickly laminated; weathers dark gray to medium dark gray, platy to chippy.	41.0
5.	Shale, grayish black, thinly laminated; weathers platy; limestone concretions 0.7 foot thick at top of interval with 3 x 1 foot concretion at base.	12.0
4.	Covered. Top of Needmore shale is in lower part of this interval; almost certain structural deformation in valley. Interval includes estimated 20 feet of Needmore Shale and 25 feet of Tioga Metabentonite at base, according to regional maps by Dennison (1961, p. 18 and 37). Tioga to Purcell interval would be about 643 feet thick, which	

		Feet
	seems excessive according to regional studies. Probably there is some repetition of section by concealed faulting or folding	502.0
	Needmore Shale (55+ feet, regional studies indicate thickness of 100 feet.)	
3.	Shale, dark gray, thinly laminated; weathers light olive gray to yellowish gray, platy to chippy; Beaver Dam facies influence; may be very slightly calcitic when fresh. This is the top exposure of Needmore.	11.0
2.	Shale, thinly to thickly laminated; weathers light olive gray, chippy; slightly to moderately calcitic.	44.0
	Oriskany Sandstone	
1.	Not measured.	

Bullpasture Mountain Section

Locality V11, located along U. S. Route 250 in Highland County, Virginia between summit of Bullpasture Mountain and valley of Cowpasture River near Headwaters. Data from Swartz, Woodward, Dennison, Hasson, and Head.

		Feet
	DEVONIAN SYSTEM	
	Brallier Formation (233+ feet)	
50.	Not measured.	
49.	Siltstone, massive ("Back Creek Member")	23.0
48.	Mostly covered.	145.0
47.	Shale with thin siltstones.	33.0
46.	Massive siltstone (section offset on this bed).	8.0
45.	Shale with thin siltstones.	24.0
	Millboro Shale (1,259 feet)	
44.	Covered, along farm lane.	182.0
43.	Shale, medium dark gray, thinly laminated, platy.	20.0
42.	Limestone, concretion zone, some septarians (Tully Member)	1.0
41.	Shale, medium dark gray, thinly laminated, platy, with scattered limestone concretions (Tully Member)	35.0
40.	Shale, medium dark gray, thinly laminated, platy.	19.0
39.	Shale, black, thinly laminated, forms stiff plates.	6.0

		Feet
38.	Shale, grayish black, thinly laminated, soft and fissile (Burket Member?)	90.0
37.	Shale, black, thickly laminated, forms stiff plates.	54.0
36.	Limestone, argillaceous to claystone, silty ("Pokejoy Limestone" - Clearville Siltstone interval).	24.0
35.	Shale, grayish black, thinly laminated, stiff and platy.	8.0
34.	Shale, silty, very dark gray, thinly to thickly laminated, weathers platy to splintery. Tongue of Mahantango Formation.	265.0
33.	Limestone concretion bed.	1.0
32.	Shale, grayish black, thinly laminated, with a few small concretions of limestone.	69.0
31.	Shale, medium dark gray, thinly laminated, calcitic, weathers platy.	3.0
30.	Shale, medium dark gray, calcitic, with fracture cleavage (7/8) and limestone, in distinct beds 0.3-0.7 foot thick (1/8). Landes Limestone Member.	30.0
29.	Shale, grayish black, thinly laminated, weathers to stiff plates.	90.0
28.	Covered.	72.0
27.	Shale, grayish black; thinly laminated, weathers to stiff plates.	14.0
26.	Shale, medium dark gray, calcitic. Top of Purcell Member.	6.0
25.	Limestone (40%) and calcitic shale (60%). Purcell Member.	8.0
24.	Shale, medium dark gray, calcitic, with scattered limestone concretions. Base of Purcell Member.	109.0
23.	Shale, grayish black, thinly laminated, platy, slightly drag folded.	76.0
22.	Covered, in highway turn.	25.0
21.	Shale, grayish black, thinly laminated, drag-folded, weathers platy.	52.0
	Tioga Bentonite (62 feet)	
20.	Shale, thinly laminated, platy to sheety, weathers yellowish gray with faint brownish cast. Tioga fauna.	17.0
19.	Shale, thinly to thickly laminated, weathers yellowish gray. Abundant Tioga fossils.	9.0
18.	Shale, thinly laminated, black (Marcellus tongue) to brownish (Tioga influence).	5.0
17.	Shale, thinly laminated, weathers platy to sheety and yellowish gray. Tioga fossils.	11.0
16.	Shale, thinly laminated, weathers platy and very dark gray to brownish gray.	2.0
15.	Shale, dark gray, thinly to thickly laminated, weathers chippy. Needmore Shale tongue.	13.0

		Feet
14.	Shale, thinly laminated, brownish black, weathers platy. Tioga Shale.	5.0
	Needmore Shale (87 feet)	
13.	Shale, dark gray, calcitic, weathers light olive gray and chippy. Calcitic shale member.	16.0
12.	Limestone, in distinct beds up to 0.6 ft. thick with calcitic shale interbeds. Calcitic shale and limestone member.	6.0
11.	Shale, dark gray, calcitic, weathers light olive gray and chippy. Calcitic shale member.	18.0
10.	Shale, grayish black, thinly laminated, weathers platy. Beaver Dam Member.	46.0
9.	Sandstone and siltstone, with phosphate nodules. Basal transition beds.	1.6
	Oriskany (Ridgeley) Sandstone (115 feet)	
8.	Sandstone, quartzose, medium to coarse, thickly to mediumly bedded, abundant fossils.	115.0
	Helderberg Group	
	Shriver Chert - Licking Creek Limestone (133 feet)	
7.	Covered; represents part of calcarenite facies interval of Little Cove Member of Licking Creek Limestone.	75.0
6.	Chert, bedded, black. Cherry Run Member of Licking Creek Limestone (Shriver Chert transition)	58.0
	Corriganville Limestone (15 feet)	
5.	Limestone, massive, gray, with interbedded white chert	15.0
	New Creek Limestone (35 feet)	
4.	Limestone, crystalline, massive, gray.	35.0
	Keyser Limestone (159 feet thickness of formation)	
3.	Jersey Shore Limestone Member (DEVONIAN)	102.0
	SILURIAN SYSTEM	
	Keyser Limestone (Silurian portion 57 feet thick)	
2.	Big Mountain Shale Member	15.0
1.	Byers Island Limestone Member	
	Tonoloway Limestone	42.0

UGR File #110
East TN State Univ. & Univ. of N.C.
May 1978

APPENDIX B

LOCATION OF DATA POINTS USED IN THIS STUDY

PENNSYLVANIA

Juniata County

P-1. Peru Mills section. Blairs Mills 7 1/2 Minute Quadrangle. Lat. 40°22'23" N, Long. 77°40'22" W. 0.7 airline miles S 70° E from Peru Mills, along county road 200 feet southwest of crossroads intersection with county road trending northeast. Complete exposure from lower Brallier Formation, entire Harrell Shale, Tully limestone concretion zone, and upper 5 feet of Mahantango Formation. Section measured July 12, 1972.

Huntingdon County

P-2. Burnt Cabins section. Burnt Cabins 7 1/2 Minute Quadrangle. Lat. 40°5'51" N, Long. 77°53'26" W. 1.5 miles due north of Burnt Cabins along loop road adjacent to U. S. Route 522 at BM 852. Complete exposure of lowest Brallier Formation, Harrell Shale, and upper 40 feet of Mahantango Formation. Section measured July 11, 1972.

P-3. Orbisonia section. Orbisonia 7 1/2 Minute Quadrangle. Lat. 40° 14'41" N, Long. 77°55'52" W. 2.0 airline miles due west of Orbisonia at intersection of two county roads at Monroe Church. Exposure of lower Brallier Formation, all of Harrell Shale and upper part of Mahantango Formation. Section measured July 13, 1972.

P-4. Saltillo section. Saltillo 7 1/2 Minute Quadrangle. Lat. 40°12' 39" N, Long. 78°1'3" W. 0.7 airline mile WSW of Saltillo along county road. Nearly complete exposure of Harrell Shale and lower part of Brallier Formation. Section measured July 13, 1972.

P-5. Huntingdon section. Huntingdon 7 1/2 Minute Quadrangle. Lat. 40° 28'44" N, Long. 78°0'54" W. Along U. S. Route 22 Bypass opposite Holiday Inn. Complete exposure of lower part of Brallier Formation, entire Harrell Shale, Tully Limestone, and upper part of Mahantango Formation. Section measured July 10, 1972.

Fulton County

P-6. Fort Littleton section. Burnt Cabins 7 1/2 Minute Quadrangle. Lat 40°3'20" N, Long. 77°57'2" W. Along county road parallel to Pennsylvania Turnpike 0.3 mile south of underpass of that road beneath Turnpike and 0.6 mile northeast of Fort Littleton Interchange. Exposure of formation contact between Brallier and Mahantango Formations shows that Harrell Shale is absent at this locality. Section described July 12, 1972.

P-7. Websters Mill section. Big Cove Tannery 7 1/2 Minute Quadrangle. Lat. 39°51'27" N, Long. 78°2'35" W. Along U. S. Route 522 at a point 0.5 mile southwest of village of Webster Mill and 0.2 mile northeast of bridge across Big Cove Creek. Exposure of base of Brallier Formation, in contact with upper part of Mahantango Formation. Harrell Shale is absent at this locality. Section described July 12, 1972.

P-8. Dogtown exposure. Hancock 7.5 Minute Quadrangle. Lat. 39°42'30" N, Long. 78°10'16" W. Road cut along county route 655 at village of Dogtown near Tonoloway Church. Located 2.2 miles north of Hancock, Maryland and 0.5 mile north of Mason and Dixon Line which forms south boundary of Pennsylvania. Brallier Formation (Fort Littleton facies with silty shale and distinctly bounded siltstones) rests directly on massive to wavy-bedded siltstone and silty shale of Mahantango Formation with no trace of Harrell Shale or Tully Limestone between them. About 20 stratigraphic feet of section is exposed; no dark shale is present. Section described September 10, 1968. This is the Hancock-Harrisonville Road section of Swartz (1913, p. 463).

P-9. Needmore exposure. Breezewood 7 1/2 Minute Quadrangle. Lat. 39° 52'58" N, Long. 78°8'16" W. Along county road 2.3 miles north of Needmore Village at a point just south of valley of Tonoloway Creek. Deeply weathered exposures show Brallier Formation in direct contact with Mahantango Formation. The Harrell Shale is absent here, although the lower Brallier seems to have fewer siltstones than is usual for the Brallier and the lower Brallier shales are a bit more platy than usual. Outcrop described July 12, 1972.

P-10. Warfordsburg section. Needmore 7 1/2 Minute Quadrangle. Lat. 39° 47'24" N, Long. 78°12'43" W. Along Interstate 70 at a point 1.7 miles north of Interchange 33 at Warfordsburg where the Interstate route intersects with U. S. Route 522. Contact between Brallier and Mahantango Formations exposed in Interstate 70 cut, with Harrell Shale absent. Exposure described July 10, 1972.

P-11. I. E. Hill well. Sun Oil Company and others. Needmore Quadrangle G. 3,050 ft S of 39°50'; 21,000 ft W of 78°10'. Rotary air drilling. Data on file at Pennsylvania Topographic and Geologic Survey.

P-12. I. C. Flinn well. Manufacturers Light and Heat. Paw Paw Quadrangle B. 8,600 ft S of 39°45'; 1,675 ft W of 78°20'. Rotary well drilling. Data on file at Pennsylvania Topographic and Geologic Survey. Geolog sample description. Formation thicknesses seem excessive, probably because of dipping strata in the hole.

Bedford County

P-13. R. Morris No. 1 well. New York State Natural Gas. Clearville Quadrangle E-7. 12,100 ft N of 39°50'; 7,300 ft E of 78°25'. Rotary air drilling completed November 9, 1960. Data on file at Pennsylvania Topographic and Geologic Survey.

P-14. Milk and Water Ridge section. Clearville 7 1/2 Minute Quadrangle. Lat. 39°53'17" N, Long. 78°27'20" W. 5.0 airline miles northeast of Chaneysville in exposure along county road 0.5 mile southwest of south end of Milk and Water Ridge and 0.2 mile east of BM 1185. Basal contact of Brallier Formation, top contact of Mahantango Formation, and much of Harrell Shale are exposed in section measured July 9, 1972.

P-15. Everett section. Clearville 7 1/2 Minute Quadrangle. Lat. 39°58' 29" N, Long. 78°23'17" W. Located along trend of hills extending northeast from main portion of Milk and Water Ridge toward Everett. Poorly exposed measured section is 3.0 airline miles southwest of Everett in cuts along county road and in exposure behind large barn. Section measured July 9, 1972.

P-16. Eichelbergertown section. Hopewell 7 1/2 Minute Quadrangle. Lat. 40°8'41" N, Long. 78°17'51" W. At Eichelbergertown along county road between crossroads in village and BM 904. Nearly complete exposure from base of Brallier Formation, through Harrell Shale, into upper part of Mahantango Formation. Section measured July 10, 1972.

P-17. Bedford section. Bedford 7 1/2 Minute Quadrangle. Lat. 40°1'24" N, Long. 78°34'56" W. 4.0 airline miles west of Bedford in cuts along Pennsylvania Turnpike at bridge across Raystown Branch of Juniata River. Complete exposure of strata in lower part of Brallier Formation, Harrell Shale, Tully Limestone, and upper part of Mahantango Formation. Section measured August 1, 1966. Exposure here was also described by Ellison (1965, p. 239-242).

P-18. Imler section. Alum Bank 7 1/2 Minute Quadrangle. Lat. 40°12'42" N, Long. 78°32'35" W. Along county road 1.0 mile northwest of Imler. Complete exposure of base of Brallier Formation, Harrell Shale, Tully Limestone, and upper part of Mahantango Formation. Section measured August 2, 1966.

Blair County

P-19. Klahr exposure. Roaring Spring 7 1/2 Minute Quadrangle. Lat. 40° 16'32" N, Long. 78°28'43" W. Along county road between Klahr and Sproul at a point 2.7 miles east from Klahr and 1.0 airline mile west from Sproul. Exposure of Harrell Shale and Tully Limestone described August 1, 1966.

P-20. Newry section. Hollidaysburg 7 1/2 Minute Quadrangle. Lat. 40° 22'47" N, Long. 78°26'6" W. 1.0 mile south of Newry along U. S. Route 220 and in hills to west of Route 220. Exposure of base of Brallier Formation, all of Harrell Shale, Tully Limestone, and upper part of Mahantango Formation. Section described August 1, 1966. Tully Limestone was described in this exposure by Heckel (1969, p. 6-8). Section of Tully Limestone and Mahantango Formation was described at this locality by Ellison (1965, p. 258-261).

P-21. Horrell section (type section of Harrell Shale). Frankstown 7 1/2 Minute Quadrangle. Lat. 40°27'13" N, Long. 78°17'31" W. At village of Horrell along access road which follows unnamed creek which enters Frankstown Branch of Juniata River at Horrell. Section from base of Brallier Formation, through Harrell Shale, Tully Limestone, and upper part of Mahantango Formation was measured August 12, 1965 and August 2, 1966. Because of an early clerical error, Butts (1918) spelled the name of the formation as Horrell Shale, and that spelling is firmly entrenched into the stratigraphic literature of the Appalachians.

P-22. Burket section. Hollidaysburg 15 Minute Quadrangle has the name Burket on the map at Lat. 40°29'30" N, Long. 78°25'28" W. The name Burket does not appear on the Hollidaysburg 7 1/2 Minute Quadrangle. The type locality of the Burket Member of the Harrell Shale (Butts, 1918, p. 524) is here, but the Burket Member is no longer exposed. A detailed plane table measurement of the type section of the Burket was made in 1958 by Wallace deWitt, Jr.; his section is used at a data point in the present report.

P-23. Pennsylvania Tract 26-A well. Phillips Petroleum Company. Edensburg Quadrangle H. 6,550 ft S of 40°20'; 350 ft W of 78°35'. Rotary air drilling. Data on file at Pennsylvania Topographic and Geologic Survey.

Cambria County

P-24. Jacob and Mary Leiden Heirs No. 1 well. Peoples Natural Gas well 4361. Patton Quadrangle D-1. 15,500 ft S of 40°45'; 9,750 ft W of 78°35'. Rotary air drilling. Data on file at Pennsylvania Topographic and Geologic Survey.

P-25. Patton No. 2 well (Burley). Kewanee Oil Co. Patton 7 1/2 Minute Quadrangle. 13,000 ft S of 40°41'; 10,900 ft W of 78°40'. Data on file at Pennsylvania Topographic and Geologic Survey.

P-26. Kubat No. 1 well. Peoples Natural Gas well 4585. Barnsboro Quadrangle I. 26,700 ft S of 40°35'; 18,250 ft W of 78°35'. Rotary drilling. Data on file at Pennsylvania Topographic and Geologic Survey.

P-27. Robert McFadden No. 1 well. Fairman Drilling Company. Johnstown Quadrangle B-9. 17,750 ft S of 40°30'; 15,400 ft W of 78°50'. Rotary air drilling. Data on file at Pennsylvania Topographic and Geologic Survey.

P-28. F. W. Heidingsfelder No. 1 well. Pennzoil-United. Johnstown Quadrangle H-10. 6,950 ft S of 40°20'; 4,475 ft W of 78°50'. Rotary air drilling. Data on file at Pennsylvania Topographic and Geologic Survey.

Somerset County

P-29. C. E. Berkey No. 1 well. Peoples Natural Gas well 4569. Somerset Quadrangle E. 27,100 ft S of 40°10'; 11,750 ft W of 79°5'. Rotary air drilling. Data on file at Pennsylvania Topographic and Geologic Survey.

P-30. C. W. Freidline No. 1 well. Belmont Oil Corp. Somerset Quadrangle F. 6,500 ft N of 40°5'; 1,150 ft E of 79°5'. Rotary air drilling. Data on file at Pennsylvania Topographic and Geologic Survey.

P-31. R. F. Henninger No. 1 well. Felmont Oil Corp. and Peoples Natural Gas. Windber Quadrangle D-2. Well was used in stratigraphic cross section by Cate (1963, p. 235), and data from that cross section was used for the present study.

P-32. R. G. Grove No. 1 well. Peoples Natural Gas Company. Windber Quadrangle C. 0.02 mile N of 40°5'; 1.06 miles E of 78°55'. Data on file at Pennsylvania Topographic and Geologic Survey.

P-33. T. C. Sipe No. 1 well. Peoples Natural Gas. Meyersdale Quadrangle D. 20,300 ft S of 40°0'; 23,100 ft W of 79°5'. Rotary air drilling. Data on file at Pennsylvania Topographic and Geologic Survey.

P-34. Nellie R. Mowry No. 1 well. Peoples Natural Gas and Snee and Eberly. Berlin Quadrangle C-1. 26,850 ft S of 40°0'; 820 ft W of 78°5'. Rotary air drilling. Data on file at Pennsylvania Topographic and Geologic Survey.

P-35. Pennsylvania Tract 64 No. 1 well. New York State Natural Gas. Meyersdale Quadrangle G-1. 7,650 ft N of 39°45'; 700 ft W of 79° 10'. Data on file at Pennsylvania Topographic and Geologic Survey.

Fayette County

P-36. Grimes No. 1 well. Sun Oil Company and others. Bruceton Quadrangle C. 9,200 ft S of 39°45'; 13,000 ft W of 79°30'. Rotary air drilling. Data on file at Pennsylvania Topographic and Geologic Survey.

P-37. Ryan No. 2 well. Zenith Company. 10,425 ft S of 39°45'; 18,000 ft W of 79°35'. Rotary air drilling. Data on file at Pennsylvania Topographic and Geologic Survey. A composite log for Harrell Shale was made, using data from this well and from the Ryan No. 1 well, located less than a mile away.

P-38. I. W. Hartman No. 1 well. Peoples Natural Gas well 3689. Bruceton Quadrangle A. 0.09 mile S of 39°45'; 0.71 mile E of 79°45'. Cable tool drilling. Data on file at Pennsylvania Topographic and Geologic Survey.

P-39. Barton No. 8 well. Manufacturers Light and Heat Company. Uniontown Quadrangle G-31. 0.74 mile N of 39°45'; 1.17 miles E of 79°45'. Cable tool drilling. Data on file at Pennsylvania Topographic and Geologic Survey.

P-40. L. F. Heyn No. 1 well. Snee and Potter Development Company. Uniontown Quadrangle. 1.23 miles N of 39°50'; 0.33 mile E of 79°50'. Cable tool and rotary drilling. Data on file at Pennsylvania Topographic and Geologic Survey. (This is the original "Summit Hotel No. 1 well" described by C. R. Fettke.)

P-41. Mueller Heirs No. 1 well. Manufacturers Light and Heat Co. Confluence Quadrangle B. 1,300 ft N of 39°50'; 7,300 ft W of 79°25'. Data on file at Pennsylvania Topographic and Geologic Survey.

P-42. Bittermore Heirs No. 1 well. Peoples Natural Gas Company. Connellsville Quadrangle I. 1.23 miles N of 40°0'; 1.48 miles W of 79°30'. Data on file at Pennsylvania Topographic and Geologic Survey.

P-43. G. G. Gault No. 1 well. Snee and Eberly and Peoples Natural Gas Company. 1,800 ft N of 40°5'; 7,700 ft W of 79°40'. Cable tool well. Data on file at Pennsylvania Topographic and Geologic Survey.

Greene County

P-44. G. W. Gordon No. 1 well. J. A. Fox and others. Waynesburg Quadrangle E-2. 9,950 ft N of 39°50'; 5,500 ft E of 80°10'. Rotary air drilling. Data on file at Pennsylvania Topographic and Geologic Survey.

Washington County

P-45. A. S. Conner well. Gulf Oil Company and J. T. Galey. Amity Quadrangle E-1. 5,300 ft N of 40°5'; 6,550 ft E of 80°10'. Data on file at Pennsylvania Topographic and Geologic Survey.

Allegheny County

P-46. Fred Backhaus No. 1 well. South Penn Oil Company. New Kensington Quadrangle E-1. 24,100 ft S of 40°40'; 22,800 ft W of 79°50'. Rotary drilling. Data on file at Pennsylvania Topographic and Geologic Survey.

P-47. Houston-Starr No. 1 well. Huntley and Huntley. Greensburg Quadrangle D-2. Well was used in stratigraphic cross section by Cate (1963, p. 233), and data from that cross section was used for the present study.

Westmoreland County

P-48. L. C. Steiner No. 5 well. American Locomotive Company. Latrobe Quadrangle G. 4,100 ft S of 40°20'; 6,000 ft W of 79°25'. Data on file at Pennsylvania Topographic and Geologic Survey.

P-49. J. Miles No. 1 well. Latrobe Quadrangle E-7. Well was used in stratigraphic cross section by Cate (1963, p. 233), and data from that cross section is used for the present study.

P-50. John Beck No. 2 well. Snee and Eberly and Peoples Natural Gas Company. Somerset Quadrangle B-2. 6,300 ft S of 40°15'; 7,100 ft W of 79°5'. Data on file at Pennsylvania Topographic and Geologic Survey.

P-51. Camillo F. Giffon well. Peoples Natural Gas Company. Latrobe Quadrangle F. 0.30 mile N of 40°20'; 0.40 mile W of 79°15'. Cable tool drilling. Data on file at Pennsylvania Topographic and Geologic Survey.

P-52. Joseph Kahl No. 1 well. Peoples Natural Gas Company. Latrobe Quadrangle F. 100 ft S of 40°25'; 6,500 ft E of 79°20'. Rotary drilling. Data on file at Pennsylvania Topographic and Geologic Survey.

Indiana County

P-53. R. S. Uncaphor No. 1 well. T. W. Phillips. Elders Ridge Quadrangle F. 8,300 ft N of 40°35'; 1,600 ft W of 79°5'. Data on file at Pennsylvania Topographic and Geologic Survey.

P-54. Susie Yosurak well. Columbia Carbon GW 1833. Indiana Quadrangle D. 15,500 ft S of 40°40'; 500 ft E of 79°15'. Air rotary drilling. Data on file at Pennsylvania Topographic and Geologic Survey.

P-55. J. R. Ralston No. 1-D well. Delta Drilling. Indiana Quadrangle F-10. 11,700 ft N of 40°35'; 2,800 ft E of 79°05'. Data on file at Pennsylvania Topographic and Geologic Survey.

P-56. J. C. Alivine No. 1 well. Felmont Oil. Indiana Quadrangle I. 18,800 ft S of 40°35'; 2,750 ft W of 79°00'. Air rotary drilling. Data on file at Pennsylvania Topographic and Geologic Survey.

P-57. James S. Blair No. 1 well. Felmont and Columbia Carbon GW 1851. Barnesboro Quadrangle G. 6,550 ft N of 40°30'; 50 ft E of 79°00'. Rotary well drilling. Data on file at Pennsylvania Topographic and Geologic Survey.

MARYLAND

Washington County

M-1. Pektonville section. Cherry Run 7 1/2 Minute Quadrangle. Lat. 39°40'6" N, Long. 78°2'42" W. Along dirt road 0.1 mile south of village of Pektonville. Brallier Formation directly overlies Mahantango Formation, and the dark shale facies of the Harrell Shale is absent. Section described July 12, 1972.

M-2. Hancock section. Hancock 7 1/2 Minute Quadrangle. Lat. 39°42'15" N, Long. 78°10'23" W. 0.5 mile northeast of Hancock in cuts along Interstate 70 0.6 mile east of interchange with U. S. Route 522. Brallier Formation directly overlies Mahantango Formation, and the dark shale facies of the Harrell Shale is absent. Section described July 12, 1972.

M-3. Woodmont section. Bellegrove 7 1/2 Minute Quadrangle. Lat. 39°37'37" N, Long. 78°17'47" W. In cut along Western Maryland Railroad 0.6 mile southeast of Woodmont. Brallier Formation with distinctly bounded siltstone beds rests directly on Mahantango Formation. Basal 66 feet of Brallier Formation contains some dark shale interbeds along with greenish gray weathering shale interbeds among the Brallier siltstone. Some influence of Harrell Shale facies can be detected here in lower Brallier, but the Harrell Shale Formation is definitely absent. This is the type exposure of the Woodmont Shale Member of the Jennings Formation, as defined by Swartz (1913, p. 468-471). The Woodmont Member is essentially replaced

by Brallier Formation in modern mapping terminology. The dark shales (related to Harrell facies) occur in the basal Woodmont here. As used by Swartz, the term Woodmont is applied to beds as old as those resting directly on top of what we call Clearville Siltstone. Section measured September 12, 1968.

Allegany County

M-4. Oldtown section. Oldtown 7 1/2 Minute Quadrangle. Lat. 39°31'33" N, Long. 78°34'5" W. In cuts along Western Maryland Railroad at BM 548 located 2.5 airline miles southeast of Oldtown. Section measured 1966.

M-5. Green Ridge section. Oldtown 7 1/2 Minute Quadrangle. Lat. 39°33'54" N, Long. 78°32'13" W. About a mile west of the crest of Green Ridge in cuts along Maniford Road near BM 695. Poorly exposed section shows basal foot of Brallier Formation, about 11 feet of Harrell Shale, and top of Mahantango Formation. Section measured September 12, 1968.

M-6. Milkhouse Hollow section. Flintstone 7 1/2 Minute Quadrangle. Lat. 39° 39'03" N, Long. 78°34'06" W. 0.2 mile north of Milkhouse Hollow in cuts along Town Creek Road at crest of hill, beside farm mail box of William E. Shriver. Located about 0.6 mile north of bridge across Town Creek and about a mile south of a commercial "beach" along Town Creek. Section measured September 14, 1968.

M-7. Flintstone exposure. Flintstone 7 1/2 Minute Quadrangle. Lat. 30°41'37" N, Long. 78°32'14" W. Along old and new locations of U. S. Route 40 at a point 1.8 miles east of Flintstone and 0.6 mile east of bridge of Route 40 across Town Creek. Brallier Formation rests directly on Mahantango Formation, with no intervening Harrell Shale. Exposure described September 14, 1968.

M-8. Spring Gap section. Patterson Creek 7 1/2 Minute Quadrangle. Lat. 39° 33'28" N, Long. 78°41'58" W. Along Western Maryland Railroad 0.9 mile east of Spring Gap village. Exposure of lower part of Harrell Shale and upper Mahantango Formation. Section measured August 4, 1966.

M-9. Pittsburgh Plate Glass Company well. Pittsburgh Plate Glass Company. Frostburg Quadrangle F. 25,900 ft S of 39°40'; 3,200 ft W of 78°45'. Data on file at Maryland Geologic Survey.

M-10. Wolfe Mill section. Evitts Creek 7 1/2 Minute Quadrangle. Lat. 39°40' 17" N, Long. 78°43'57" W. On east side of U. S. Route 40 at a point 0.4 road miles west of Wolfe Mill. Complete exposure of lower part of Brallier Formation, Harrell Shale, Tully Limestone, and upper part of Mahantango Formation. Section measured August 4, 1966.

M-11. Corriganville section. Cumberland 7 1/2 Minute Quadrangle. Lat. 39° 41'45" N, Long. 78°47'30" W. In north edge of Corriganville, on east side of small valley. Exposure of lower part of Brallier Formation, Harrell Shale, Tully Limestone, and upper part of Mahantango Formation. Upper part of Harrell Shale is poorly exposed and drag-folded, so a good thickness determination is impossible. Section measured July 12, 1962 and July 1965.

M-12. LaVale section. Cumberland 7 1/2 Minute Quadrangle. Lat. 39°38'23" N, Long. 78°49'53" W. In village of LaVale, near U. S. Route 40 in excavations behind Maryland State Police building. Exposure of lower Brallier Formation, Harrell Shale, and upper Mahantango Formation. Upper part of Harrell Shale is omitted by a fault. Section measured July 20, 1962 and July 1965.

M-13. Pinto section. Cresaptown 7 1/2 Minute Quadrangle. Lat. 39°34'26" N, Long. 78°51'15" W. 0.8 mile northwest of village of Pinto along stream valley 0.25 mile northwest of U. S. Route 220. Poorly exposed section of Brallier, Harrell, and Mahantango Formations measured July, 1962.

M-14. Dawson section. Keyser 7 1/2 Minute Quadrangle. Lat. 39°29'06" N, Long. 78°56'38" W. Harrell Shale, Tully Limestone, and Mahantango Formation exposed in cuts beside and behind general store along U. S. Route 220 at Dawson and in stream bed on west side of Route 220 520 feet northeast of that general store. Top contact of Harrell Shale is not exposed. Sections measured August 25, 1961 and July 24, 1965.

M-15. McCoole exposure. Keyser 7 1/2 Minute Quadrangle. Lat. 39°26'56" N, Long. 78°58'19" W. In cut along U. S. Route 220 in north edge of McCoole, at northwest end of large bend in highway. Lower Brallier Formation, Harrell Shale, Tully Limestone, and top portion of Mahantango Formation. Too structurally distorted to permit measurement of a section, but stratigraphic succession can be deciphered. Exposure described July 24, 1965.

Garrett County

M-16. Robeson No. 1 well. Superior Oil Company. Permit 7,613. Lat. 39°38' 10" N, Long. 79°03'01" W. Data from Amsden (1954, Plate III).

M-17. Katherine Shartzer (Humbertson) No. 1 well. New Penn Development Company and others. Accident Quadrangle, EC. 2.18 miles S of 39°40'; 3.97 miles W of 79°15'. Sample description by Martens (1945, p. 752-758).

M-18. Shaw No. 2 well. New York State Natural Gas well N-247. 5,900 ft S of 39°25'; 9,525 ft W of 79°20'. Geolog sample description.

M-19. Baker No. 1 well. Snee and Eberly. Permit 6,951. Lat. 39°23'35" N, Long. 79°23'02" W. Data from Amsden (1954, Plate III).

WEST VIRGINIA

Berkeley County

W-1. Hedgesville exposure. Big Pool 7 1/2 Minute Quadrangle. Lat. 39°33' 29" N, Long. 78°00'10" W. In exposure along West Virginia Route 9 0.5 mile northwest of main intersection in Hedgesville. About 25 feet of grayish black, fissile shale at Harrell Shale stratigraphic position occurs in axis of syncline. Outcrop examined September 16, 1968.

W-2. Shanghai exposure. Glengary 7 1/2 Minute Quadrangle. Lat. 39°26'47" N, Long. 78°08'29" W. Along county road 0.6 mile west of Shanghai. About 25 feet of grayish black shale overlies Mahantango Formation and underlies Brallier Formation. Outcrop examined September 16, 1968.

Morgan County

W-3. Burnt Factory exposure. Hancock 7 1/2 Minute Quadrangle. Lat. 39°39' 18" N, Long. 78°11'58" W. 2.4 miles northeast of Berkeley Springs along road between village of Burnt Factory and Fairview Church. Brallier Formation directly overlies Mahantango Formation, with no indication of dark shales of Harrell Shale lithology. Exposure examined September 16, 1966.

W-4. Bethel Church section. Great Cacapon 7 1/2 Minute Quadrangle. Lat. 39°33'43" N, Long. 78°15'21" W. 0.4 miles southeast of U. S. Route 522 along county road at a position 0.7 road miles northeast of Bethel Church. 10 feet of Harrell Shale occurs between Brallier Formation and Mahantango Formation. Section measured September 16, 1968.

W-5. Rock Gap Run exposure. Great Cacapon 7 1/2 Minute Quadrangle. Lat. 39°31'17" N, Long. 78°16'17" W. Along county road beside Rock Gap Run at a point 0.5 road miles southeast of U. S. Route 522. Brallier Formation overlies Mahantango Formation with dark Harrell Shale absent. 24 feet of Brallier lithology shale (medium dark gray, thickly to thinly laminated shale) occurs between the siltstones of the Brallier and Mahantango Formation; this 24 feet of shale is not dark enough to call Harrell Shale, but it occurs at expected position of Harrell dark shale facies. Exposure described September 16, 1968.

W-6. Great Cacapon exposure. Great Cacapon 7 1/2 Minute Quadrangle. Lat. 39°34'43" N, Long. 78°19'40" W. Along West Virginia Route 9 3.7 miles southwest of village of Great Cacapon and 0.1 mile northeast of junction of Wiggins Run with Long Hollow Run. Brallier Formation rests directly on Mahantango Formation with Harrell Shale absent. Shales in lower part of Brallier Formation are medium gray, thinly to thickly laminated, and platy weathering; they are not dark enough to call Harrell Shale. This exposure is approximately at the zero isopach of the Harrell Shale, and the exposure has a little more dark shale influence than the section at Woodmont (section M-3). Exposure described September 16, 1968.

Hampshire County

W-7. South Branch section. Oldtown 7 1/2 Minute Quadrangle. Lat. 39°31'06" N, Long. 78°34'15" W. Along French Station road 0.3 mile southeast of village of South Branch (French Station) and 2.6 miles southeast of Oldtown, Maryland. Complete exposure of lower part of Brallier Formation, Harrell Shale, and upper part of Mahantango Formation. Section measured September 14, 1968.

W-8. Millesons Mill exposure. Springfield 7 1/2 Minute Quadrangle. Lat. 39° 27'01" N, Long. 78°38'01" W. Along county road 2.5 airline miles northeast of Millesons Mill. Harrell Shale is 41 feet thick and occurs beneath Brallier Formation and above Mahantango Formation. The interval 30-71 feet above top of Clearville siltstone is platy to chippy, light olive

gray weathering shale, but not as dark as usual for the Harrell Shale. Exposure described September 14, 1968.

W-9. Raven Rocks section. Capon Bridge 7 1/2 Minute Quadrangle. Lat. 39° 21'20" N, Long. 78°29'54" W. 1.3 miles north of Raven Rocks on west side of North River valley along road leading to Keyser Country Club. In a poorly exposed section the Harrell Shale is 6 to 20 feet thick; the Harrell underlies Brallier Formation and overlies the Mahantango Formation. Section measured September 14, 1968.

W-10. Timber Ridge exposure. Capon Bridge 7 1/2 Minute Quadrangle. Lat. 39° 17'25" N, Long. 78°24'03" W. 0.6 mile west of the West Virginia-Virginia boundary along U. S. Route 50 at a position 300 feet east of intersection with Timber Ridge road. 19 feet of shale lacking siltstone interbeds occurs beneath Brallier Formation and above siltstones of the Mahantango Formation; this is chippy to lumpy to platy and is very weathered to moderate yellowish brown to reddish gray. This is apparently the feather edge of Harrell Shale facies influence. The zero Harrell Shale isopach should pass just east of this data point. If the stratigraphic identification is correct for this exposure, then the top of the Mahantango Formation is incorrectly mapped on the geologic map of West Virginia. Outcrop described August 9, 1966.

W-11. Rio section. Rio 7 1/2 Minute Quadrangle. Lat. 39°08'17" N, Long. 78° 39'45" W. At concrete highway bridge across North River 0.3 mile east of Rio. Exposure of basal Brallier Formation, entire Harrell Shale, and top part of Mahantango Formation. Section measured August 9, 1966.

W-12. Devil Hole Run section. Sector 7 1/2 Minute Quadrangle. Lat. 39°12'41" N, Long. 78°50'32" W. Along north side of Devil Hole Run 1.4 miles southeast of village of Sector. Complete exposure of lower Brallier Formation, Harrell Shale, and upper Mahantango Formation. Section measured August 9, 1966.

W-13. Junction section. Romney 7 1/2 Minute Quadrangle. Lat. 38°18'56" N, Long. 78°52'12" W. Along U. S. Route 50 0.6 mile west of intersection of U. S. Routes 50 and 220 at Junction. Complete exposure of lower portion of Brallier Formation, Harrell Shale, and upper portion of Mahantango Formation. Section measured August 9, 1966.

Mineral County

W-14. Burlington section. Burlington 7 1/2 Minute Quadrangle. Lat. 39°20'22" N, Long. 78°55'26" W. Along U. S. Route 50 0.3 miles west of Burlington, in composite section exposed on both limbs of a syncline. Complete exposure of lower portion of Brallier Formation, Harrell Shale, Tully Limestone, and upper portion of Mahantango Formation. Section measured August 8, 1966.

W-15. Staggs Run exposure. Keyser 7 1/2 Minute Quadrangle. Lat. 39°23'19" N, Long. 78°52'59" W. Roadside outcrop along Staggs Run. Excellent exposure of contorted Harrell Shale at crest of Tussey Mountain anticline. Outcrop described July, 1962.

W-16. Ridgeville section. Burlington 7 1/2 Minute Quadrangle. Lat. 39°20'51" N, Long. 78°59'23" W. Along U. S. Route 50 0.2 mile east of crossroads in village of Ridgeville. Part of upper Harrell Shale is concealed in a section spanning lower Brallier Formation, Harrell Shale, and upper Mahantango Formation. Section measured August 8, 1966.

W-17. O'Neil Gap section. Keyser 7 1/2 Minute Quadrangle. Lat. 39°26'07" N, Long. 78°54'44" W. 4 miles east of Keyser along stream leading from O'Neil Gap toward Cabin Run. Exposure of lower portion of Brallier Formation, Harrell Shale, and upper Mahantango Formation. Section measured September 7, 1961.

W-18. Knobly Tunnel section. Cresaptown 7 1/2 Minute Quadrangle. Lat. 39°33' 39" N, Long. 78°47'34" W. In cuts along dirt road on north side of Baltimore and Ohio Railroad 0.3 mile east of entrance of Knobly Tunnel. Exposure of lower portion of Brallier Formation, Harrell Shale, and upper part of Mahantango Formation. Section measured August 1965.

W-19. Keyser section. Keyser 7 1/2 Minute Quadrangle. Lat. 39°26'10" N, Long. 78°59'15" W. Section measured along and near Chestnut Street in road gutters and construction excavations and along street leading from this vicinity toward Potomac State College. Exposures of parts of Brallier Formation, Harrell Shale and Mahantango Formation. Section measured August 16, 1961 and July 27, 1965.

W-20. F. B. Davis No. 1 well. Pittsburgh Plate Galss. 23,700 ft S of 39°30'; 6,200 ft W of 79°00'. Geolog sample description.

W-21. King Run section. Westernport 7 1/2 Minute Quadrangle. Lat. 39°22'59" N, Long. 79°02'04" W. In stream bed and along banks of King Run 0.6 mile upstream from confluence with New Creek at village of New Creek. Exposure of lower Brallier Formation, most of Harrell Shale, and upper Mahantango Formation. Section measured August, 1965.

W-22. Ash Spring Run section. Antioch 7 1/2 Minute Quadrangle. Lat. 39°21'16" N, Long. 79°03'17" W. Exposures along southwest fork of Ash Spring Run permit measurement of poor section spanning Brallier Formation, Harrell Shale, and upper Mahantango Formation. Section measured August 23, 1965.

W-23. Claysville section. Antioch 7 1/2 Minute Quadrangle. Lat. 39°20'37" N, Long. 79°04'12" W. Along unnamed tributary to New Creek at a location 0.1 mile northwest of Claysville Church at intersection of U. S. Route 50 and West Virginia Route 93. Complete exposure of lower Brallier Formation, Harrell Shale, and upper Mahantango Formation. Section measured in 1963 and August, 1965.

W-24. Pokejoy Run section. Antioch 7 1/2 Minute Quadrangle. Lat. 39°18'33" N, Long. 79°05'53" W. In bed of Pokejoy Run 0.3 mile upstream from junction with New Creek. Exposure of lower Brallier Formation, part of Harrell Shale, and upper part of Mahantango Formation. This is type section of Pokejoy Member carbonate unit in Mahantango Formation (Hasson and Dennison, 1974). Section measured July 17, 1964 and August, 1965.

Hardy County

W-25. Wardensville section. Wardensville 7 1/2 Minute Quadrangle. Lat. 39°05'06" N, Long. 78°32'23" W. Along West Virginia Route 55 3 airline miles east of Wardensville and 0.1 mile west of Marvin Chapel. Complete exposure of lower part of Brallier Formation, Harrell Shale, and upper Mahantango Formation. Section measured 1966.

W-26. Lost City section. Lost City 7 1/2 Minute Quadrangle. Lat. 38°54'09" N, Long. 78°51'08" W. 2.3 miles southwest of Lost City Church along West Virginia Route 259; exposure is along dirt road along valley of Strawderman Hollow with base of section at intersection with Route 259. Entire exposure is very deeply weathered. Outcrop has complete exposure of lower Brallier Formation, Harrell Shale, and upper Mahantango Formation.

W-27. G. Funkhouser No. 1 well. Sun Oil Company. 15,050 ft S of 39°0'; 15,425 ft W of 78°50'. Permit Hardy-14. Rotary drilling. Geolog sample description.

W-28. Anna Baughman No. 1 well. United Fuel Gas Company. 26,000 ft S of 39°05'; 13,600 ft W of 78°45'. Permit Hardy-3. Rotary air drilling. Geolog sample description.

W-29. Henry and Ella Davidson well. United Fuel Gas Company. 1.98 miles S of 39°10'; 1.88 miles W of 78°45'. Permit Hardy-2. Geolog sample description.

W-30. Fisher section. Rig 7 1/2 Minute Quadrangle. Lat. 39°02'26" N, Long. 79°02'10" W. 2.1 miles southwest of Fisher along county road which follows Hutton Run. Excellent exposure of Tully Limestone and part of Harrell Shale. Section measured 1966.

W-31. Flats exposure. Old Fields 7 1/2 Minute Quadrangle. Lat. 39°11'45" N, Long. 78°58'05" W. Exposures of Harrell Shale along Markwood Road 0.8 mile east of Flats. Outcrop visited 1966.

W-32. Landes section. Petersburg West 7 1/2 Minute Quadrangle. Lat. 38°53' 24" N, Long. 79°12'23" W. Along small unnamed stream behind home of Mrs. Audrey Kesner. Nearly complete exposure of lower part of Brallier Formation, Harrell Shale, and upper part of Mahantango Formation. This is type section of Landes Limestone Member of Mahantango Formation. Section measured August 4, 1965.

W-33. Petersburg section. Maysville 7 1/2 Minute Quadrangle. Lat. 39°01'40" N, Long. 79°08'09" W. Along county road which intersects west side of West Virginia Route 42 at a point 1.9 road miles northeast of intersection of West Virginia Routes 42 and 28 at north edge of Petersburg. This section is along road which follows north edge of valley of Robinson Run at a point 0.4 mile west of Route 42 along this county road. Essentially a continuous exposure of lower part of Brallier Formation, Harrell Shale, and upper Mahantango Formation. Section measured August 9, 1973.

W-34. Hopeville section. Hopeville 7 1/2 Minute Quadrangle. Lat. 38° 57'25" N, Long. 79°17'40" W. Along West Virginia Route 28 0.8 mile south of village of Hopeville and along dirt road on north edge of valley of Moyer Run. Complete section of lower part of Brallier Formation, Harrell Shale, Mahantango Formation, Marcellus Shale, Tioga Bentonite, and Needmore Shale can be pieced together here, with thickness reliability of varying quality. This is very near the southwestern limit of recognizable Harrell, Mahantango, and Marcellus Formations and the north limit of Millboro Shale in this outcrop belt, but the top of the Mahantango is recognizable by a limestone concretion zone, which is probably the Pokejoy horizon. Section measured 1963, 1965.

W-35. Hopeville Gap section. Blackbird Knob 7 1/2 Minute Quadrangle. Lat. 39°0'6" N, Long. 79°16'1" W. Along farm road and beneath chicken house (now torn down) at a point 0.1 mile west of Jordan Run road. Complete exposure of lower Brallier Formation, Harrell Shale, and Mahantango Formation. Section measured August 15, 1962.

W-36. Eureka School section. Maysville 7 1/2 Minute Quadrangle. Lat. 39°6'27" N, Long. 79°13'33" W. At site of Eureka School (now abandoned) shown on 1:62,500 scale geologic map of Grant County; Harrell Shale and upper Mahantango Formation are exposed along road and beside farm pond on north side of North Fork of Lunice Creek. Section measured July 21, 1965.

W-37. Scherr section. Greenland Gap 7 1/2 Minute Quadrangle. Lat. 39° 11'44" N, Long. 79°10'29" W. In cuts along West Virginia Route 42 0.3 mile northwest of main highway intersection in the village of Scherr, and at corresponding stratigraphic position in exposures along the creek which passes beneath Route 42 0.2 mile northwest of the same highway intersection. Nearly complete exposures of Brallier Formation, Harrell Shale, and Mahantango Formation. Section measured August 1, 1962 and July 21, 1965.

W-38. Elklick Run section. Greenland Gap 7 1/2 Minute Quadrangle. Lat. 39°13'10" N, Long. 79°9'41" W. 2.0 airline miles northeast of main highway intersection in village of Scherr; outcrops are along west side of valley of Elklick Run beside farm road 0.1 mile northwest of West Virginia Route 93. Exposures of lower Brallier Formation, Harrell Shale, and Tully Limestone. Section measured 1965.

W-39. Keyser Reservoir section. Mount Storm 7 1/2 Minute Quadrangle. Lat. 39°16'13" N, Long. 79°7'56" W. Stratigraphic thicknesses of Mahantango and Harrell Shale pieced together from inclined cores drilled for foundation testing at dam of water supply reservoir section measured 1963.

W-40. Kittlelick Ridge South outcrop. Mount Storm 7 1/2 Minute Quadrangle. Lat. 39°16'48" N, Long. 79°7'33" W. Exposures along northeast tributary at southwest end of Kittlelick Ridge and 0.7 mile northeast of dam of Keyser Reservoir. Exposures of Brallier Formation and Harrell Shale. Outcrop described August 24, 1965.

W-41. Kittlelick Ridge North section. Antioch 7 1/2 Minute Quadrangle. Lat. 39°17'53" N, Long. 79°6'37" W. 0.2 mile southwest of Mineral-Grant County border and 0.3 mile northwest of New Creek, at north end of Kittlelick Ridge along a small stream. Exposure of lower Brallier Formation, Harrell Shale, and upper Mahantango Formation. Section measured August 18, 1965.

Pendleton County

W-42. Brushy Run section. Mozer 7 1/2 Minute Quadrangle. Lat. 38°50'8" N, Long. 79°14'37" W. Along bank of Brushy Run and especially along county road 0.2 mile southeast of intersection with U. S. Route 220 at village of Brushy Run. Exposures of Harrell Shale and Brallier Formation. Section measured August 19, 1973.

W-43. Mouth of Seneca North section. Upper Tract 7 1/2 Minute Quadrangle. Lat. 38°50'14" N, Long. 79°22'28" W. At village of Mouth of Seneca 0.2 mile northeast of Seneca Creek along dirt road 0.1 mile west of its intersection with West Virginia Route 28. Exposure of Brallier Formation, most of Millboro Shale, and Needmore Shale. Section measured August 29, 1962 and 1965.

W-44. Mouth of Seneca South section. Onego 7 1/2 Minute Quadrangle. Lat. 38°49'47" N, Long. 79°22'43" W. On north side of U. S. Route 33 0.4 mile south of highway intersection in village of Mouth of Seneca. Exposure of lower part of Brallier Formation, Millboro Shale, and part of Needmore Shale. Section measured August 29, 1962 and 1965.

W-45. Ketterman Knob section. Onego 7 1/2 Minute Quadrangle. Lat. 38° 46'16" N, Long. 79°25'7" W. In roadside shale quarry at sharp bend in U. S. Route 33 1.0 mile southeast of Ketterman Knob and 5.4 road miles southwest of highway intersection in village of Mouth of Seneca. Complete exposure of Brallier Formation, Millboro Shale, and upper part of Needmore Shale. Section measured June 1963; August 29, 1965; and June, 1966.

W-46. Judy Gap section. Circleville 7 1/2 Minute Quadrangle. Lat. 38°42' 19" N, Long. 79°28'11" W. Along bank of North Fork of South Branch of Potomac River 0.3 mile upstream from bridge at junction of West Virginia Route 28 and U. S. Route 33 at village of Judy Gap. Complete exposure of lower Brallier Formation, Millboro Shale, and upper part of Needmore Shale. Section measured June 26, 1963 and 1965.

W-47. Dry Run section. Snowy Mountain 7 1/2 Minute Quadrangle. Lat. 38° 36'55" N, Long. 79°31'41" W. Along south side of Dry Run 0.8 mile upstream from junction of Dry Run with the North Fork of South Branch of Potomac River. Incomplete exposure of lower part of Brallier Formation and Millboro Shale. The Millboro Shale is in fault contact with the Oriskany Sandstone. Section measured August, 1963 and June 7, 1969.

Pocahontas County

W-48. Frost section. Cass 15 Minute Quadrangle. Lat. 38°16'54" N, Long. 79°53'2" W. 0.7 mile north of village of Frost and 0.2 mile southeast of abandoned Cove Hill School (now a house) along a county road 0.4 mile northwest of its intersection with West Virginia Route 28 0.5 mile north of Frost. Exposure of lower Brallier Formation, Harrell Shale, Tully Limestone, Tioga Bentonite, Needmore Shale, and Huntersville Chert. Section measured August 18, 1966.

W-49. Dilleys Mill section. Cass 15 Minute Quadrangle. Lat. 38°15'10" N, Long. 79°57'31" W. 1.2 miles southeast of village of Dilleys Mill along a county road 0.5 road miles northeast from its junction with the main paved road between Huntersville and Greenbank. Partial exposure of lower Brallier Formation, Millboro Shale, and Huntersville Chert. Section measured August 23, 1973.

W-50. M-1 USA well. Columbian Carbon GW-1355. Spruce Knob 15 Minute Quadrangle. 3.64 miles S of 38°35'; 1.81 miles W of 79°40'. Permit Pocahontas-19. Geolog sample description.

W-51. L-1 USA well. Columbian Carbon GW-1329. Spruce Knob 15 Minute Quadrangle. 2.35 miles S of 38°35'; 0.88 mile west of 79°40'. Permit Pocahontas-18. Geolog sample description.

W-52. E-1 USA well. Columbia Carbon well 1220. Durbin Quadrangle. 1.19 miles W of 79°45'; 0.98 mile S of 38°40'. Permit Pocahontas-4. Cable tool drilling. Geolog sample description.

Randolph County

W-53. A. W. Ewing No. 1 well. Hope Natural Gas well 10,296. Pickens Quadrangle. 3.19 miles S of 38°40'; 3.88 miles W of 80°5'. Permit Randolph-111. Rotary air drilling. Geolog sample description.

W-54. Elva Simons No. 1 well. Cumberland and Allegheny Gas Company. Elkins Quadrangle. 3.37 miles S of 38°50'; 4.57 miles W of 79°50'. Permit Randolph-2. Cable tool drilling. Sample description by Martens (1945, p. 514-517). Tully Limestone occurs at depth 1075-1100 feet.

W-55. U. S. Department of Interior. Consolidated Gas Supply well 10,000. Spruce Knob Quadrangle. 9,300 ft S of 38°45'; 19,500 ft W of 79°40'. Permit Randolph-86. Cable tool drilling. Geolog sample description.

W-56. D. H. Hill-Arnold. Consolidated GW-1293. Horton Quadrangle. 3.38 miles S of 38°50'; 1.78 miles W of 79°40'. Permit Randolph 101-D. Rotary drilling. Geolog sample description.

W-57. U. S. Department of Interior. Hope Natural Gas GW-9999. 18,900 ft S of 38°55'; [illegible] ft W of 79°55'. Permit Randolph-89. Geolog sample description.

W-58. Kerens outcrop. Montrose 7 1/2 Minute Quadrangle. Lat. 39°0'41" N, Long. 79°50'23" W. 1.4 air miles west of village of Kerens along bank of county road and in bed of Davis Lick Creek. Black shales exposed here are probably Millboro Shale in core of anticline. Exposures are too poor to permit any thickness measurements. Exposure visited 1966, 1977. The Endress Hartman No. 1 well (Permit Randolph-1) was drilled near these outcrops and encountered apparent Tully Limestone at depth 1046-1085 feet (Martens, 1939, p. 116), so there is probably faulting in the Devonian shales, or the top of the black shale facies is much higher stratigraphically than along the Allegheny Front outcrop belt to the east. Woodward (1943, p. 349) regards thin limestone reported from this outcrop belt as possibly Tully Limestone but more likely a calcareous zone in the Harrell Shale (Millboro Shale of our terminology). We have been unable to locate any limestone outcrops in the Millboro Shale near Kerens.

Tucker County

W-59. West Virginia Power and Transmission Company (Kaemmerling Trustee) No. 1 well. The Ohio Oil Company. Davis Quadrangle. 0.25 mile S of 39°5'; 3.52 miles W of 79°20'. Permit Tucker-1. Cable tool drilling. Sample description by Martens (1945, p. 557-567). Apparent Tully Limestone at depth 7322-7335 feet.

W-60. Jason Harmon No. 1 well. Cumberland and Allegheny Gas Company. Davis Quadrangle. 2.08 miles S of 39°5'; 4.38 miles W of 79°20'. Permit Tucker-4. Cable tool drilling. Geolog sample description.

W-61. Kuykendall No. 1 well. The Ohio Oil Company. Davis Quadrangle. 1.39 miles S of 39°5'; 4.07 miles W of 79°20'. Permit Tucker-2. Rotary drilling. Geolog sample description.

W-62. United States of America No. C-1. Columbian Carbon GW-1215. Parsons Quadrangle. 5.63 miles S of 39°15'; 2.88 miles W of 79°35'. Permit Tucker-13. Cable tool drilling. Geolog sample description.

W-63. Ira E. Nestor well. Hope Natural Gas Company well 9924. Belington Quadrangle. 2.85 miles S of 39°15'; 0.82 mile W of 79°45'. Permit Tucker-11. Cable tool drilling. Sample study by William Henry on file with Hope Natural Gas.

Preston County

W-64. United States of America Q-1 No. 1 well. Columbian Fuel Corp. Parsons Quadrangle. 4,300 ft S of 39°15'; 21,000 ft W of 79°30'. Permit Preston-119. Rotary air drilling. Geolog sample study.

W-65. Cora E. Lewis No. 1 well. Cumberland and Allegheny Gas Company. Kingwood Quadrangle. 4.62 miles S of 39°30'; 3.62 miles W of 79° 30'. Permit Preston-33. Sample study by Cardea (1959, p. 177-181).

W-66. A. Walls No. 1 well. Phillips Petroleum Company. Thornton Quadrangle. 2.39 miles S of 39°30'; 2.00 miles W of 79°50'. Permit Preston-86. Rotary air and mud drilling. Geolog sample study.

W-67. L. C. Feather well. Consolidated Gas Supply well 11,000. Bruceton Mills Quadrangle. 21,350 ft S of 39°35'; 19,850 ft W of 79°40'. Permit Preston-132. Geolog sample study.

Marion County

W-68. R. R. Finch well. Phillips Petroleum Company. Fairmont Quadrangle. Lat. 39°25' N; Long. 80°2' W. Permit Marion-244. Geolog sample study.

Monongalia County

W-69. H. C. Greer et al. well. Hope Natural Gas Company well 8526. Morgantown Quadrangle. 1.2 miles W of 79°50'; 0.45 mile S of 39°35'. Permit Monongalia-128. Sample description by Martens (1945, p. 448-455).

W-70. Fred Born et al. well. Phillips Petroleum. Morgantown Quadrangle. 3.41 miles S of 39°35'; 1.80 miles W of 79°50'. Permit Monongalia-274. Geolog sample description.

VIRGINIA

Frederick County

V-1. Gore section. Gore 7 1/2 Minute Quadrangle. Lat. 39°15'55" N, Long. 78°20'7" W. On west flank of a small anticline exposed along U. S. Route 50 0.2 mile west of the intersection of Route 50 and Virginia Route 704 in the village of Gore. Brallier Formation directly overlies Mahantango Formation, and there is no Harrell Shale present. Section measured August 10, 1966.

V-2. Gainsboro section. White Hall 7 1/2 Minute Quadrangle. Lat. 39° 15'48" N, Long. 78°14'7" W. Along U. S. Route 522 1.5 miles east of intersection of Route 522 with Virginia Route 600 in Gainsboro and 0.4 mile southeast of Route 522 bridge across Hogue Creek. Brallier Formation directly overlies Mahantango Formation, and there is no Harrell Shale present. Exposure described August 13, 1971.

V-3. Hayfield section. Hayfield 7 1/2 Minute Quadrangle. Lat. 39°13'15" N, Long. 78°16'31" W. 1.2 miles southeast along U. S. Route 50 from crossroads with Virginia [illegible] in village of Hayfield, and 0.35 miles southeast [illegible] Route 50 across Hogue Creek. [illegible] Formation directly overlies Mahantango Formation, with no Harrell Shale present. [illegible] feet above the top of the Mahantango [illegible] no siltstones in Brallier formation [illegible] feet thick, but there is no sign of dark coloration [illegible] lower Brallier. Section measured August 13, 1971.

V-4. Chambersburg section. Winchester 7 1/2 Minute Quadrangle. Lat. 39° 11'55" N, Long. 78°14'56" W. Along northeast edge of U. S. Route 50 at its intersection with Virginia Route 608 leading south toward Mount Williams. This intersection is a mile west of the old village of Chambersville (now called the village of Round Hill). Brallier Formation rests directly on Mahantango Formation; the interval 24 to 29 ft above the base of the Brallier is thinly to thickly laminated, medium dark gray to dark gray shale, and represents faint tongue of Harrell Shale influence, but too weakly developed to call true Harrell Shale. Base of Brallier Formation is at concrete highway marker labeled 38M. Section measured August 13, 1971.

Shenandoah County

V-5. Wheatfield exposure. Middletown 7 1/2 Minute Quadrangle. Lat. 39° 4'29" N, Long. 78°22'29" W. Exposures along Virginia Route 55 0.3 mile west of village of Wheatfield. Brallier Formation rests directly on Mahantango Formation with Harrell Shale facies absent. Exposure examined August 14, 1971.

V-6. Liberty Furnace section. Wolf Gap 7 1/2 Minute Quadrangle. Lat. 38°53'22" N, Long. 78°41'16" W. 1.25 miles northeast of old iron furnace of Liberty Furnace, in cuts along Virignia Route 690 at its intersection with Virginia Route 717. Complete exposure of lower part of Brallier Formation, Harrell Shale, and upper part of Mahantango Formation. Section measured August 16, 1973.

V-7. Kipps Gap section. Timberville 7 1/2 Minute Quadrangle. Lat. 38° 44'33" N, Long. 78°46'33" W. At Kipps Gap along Virginia Route 726 0.3 mile southeast of bridge of that road across Mill Creek. Poorly exposed section of lower part of Brallier Formation, Harrell Shale, and Mahantango (?) Formation. Section measured August 17, 1973.

Rockingham County

V-8. Tunis section. Timberville 7 1/2 Minute Quadrangle. Lat. 38°42'53" N, Long. 78°52'6" W. Along Virginia Route 610 2.5 miles southwest of Shenandoah-Rockingham County boundary and 0.75 mile north of village of Tunis. Exposures nearly parallel with strike of strata; exposures of lower Brallier Formation, Harrell Shale, and upper part of Mahantango Formation. Section measured August 17, 1973.

V-9. R. J. Whetzell well Shell et al. Orkney Springs Quadrangle. 25,000 ft S of 38°50' N; 11,000 ft W of 78°55'. Rotary drilling. Geolog sample description.

Highland County

V-10. Bertha Smith No. 1 well. Pennzoil United. McDowell Quadrangle. 900 ft S of 38°15'; 1,900 ft W of 79°20'. Rotary drilling. Geolog sample description.

V-11. Bullpasture Mountain section. McDowell 7 1/2 Minute Quadrangle. Lat. 38°19'30" N, Long. 79°26'19" W. Along U. S. Route 250 on southeast flank of Bullpasture Mountain, along U. S. Route 250 0.2 miles east of bridge across Cowpasture River, in exposures along Virginia Route 614 on west side of Cowpasture River valley, and along Black Gum Draft in lower 0.1 mile upstream from its confluence with the Cowpasture River. Exposures of lower part of Brallier Formation, Millboro Shale, and Needmore Shale. Section measured 1966.

V-12. Straight Fork (Route 642) section. Monterey 7 1/2 Minute Quadrangle. Lat. 38°29'51" N, Long. 79°36'38" W. Along Virginia Route 642 between crest of Lantz Mountain and bridge across Straight Fork. Rather deeply weathered continuous section can be pieced together of lower Brallier Formation, Millboro Shale, and Needmore Shale. Section measured August 26, 1962 and August, 1965.

V-13. Back Creek (Route 250) section. Hightown 7 1/2 Minute Quadrangle. Lat. 38°27'7" N, Long. 78°38'54" W. 0.3 highway miles east of bridge across Back Creek in cuts along U. S. Route 250 and in fields on north side of highway. Nearly complete exposure of lower part of Brallier Formation, Millboro Shale, and Needmore Shale. Section measured August, 1965; August, 1966; and April 8, 1969.

Bath County

V-14. Mountain Grove section. Mountain Grove 7 1/2 Minute Quadrangle. Lat. 38°5'58" N, Long. 79°53'15" W. In stream bed of Little Back Creek at village of Mountain Grove. Fairly continuous exposures of lower part of Brallier Formation, Millboro Shale, Needmore Shale, and Huntersville Chert; parts of the exposure are affected by drag-folds. Millboro Shale section measured August 20, 1966.

V-15. Thompson Creek section. Bath Alum 7 1/2 Minute Quadrangle. Lat. 38°2'39" N, Long. 79°21'8" W. Exposures along both sides of Virginia Route 39, along side roads, and along valley of Thompson Creek. Purcell Limestone Member of Millboro Shale occurs just west of bridge of Route 39 across Thompson Creek. Exposures of lower part of Brallier Formation, Millboro Shale, and Tioga Bentonite at top of Needmore Shale. Section measured August 20, 1966.

V-16. Millboro Springs section. Millboro, Nimrod Hall, and Bath Alum Springs 7 1/2 Minute Quadrangles. Lat. 37°59'46"N, Long. 79°37'30" W. In exposures along Virginia Route 39 and in fields, driveways, and along creeks on both sides of Route 39 at village of Millboro Springs. Fairly continuous exposures of lower part of Brallier Formation, Millboro Shale, and lower part of Needmore Shale. This is type section of Millboro Shale. Section measured August, 1965.

V-17. Panther Gap section. Green Valley and Millboro 7 1/2 Minute Quadrangles. Lat. 38°0'0", Long. 79°[illegible]0" W. Along Chesapeake and Ohio Railroad 0.4 mile northeast of Bath-Alleghany County boundary at Panther Gap. Exposures of Brallier Formation, Millboro Shale, and Needmore Shale. Brallier seems to be in normal contact with lower Millboro. Lower part of Needmore Shale is exposed on

north side of Virginia Route 39 0.3 mile east of Bath-Rockbridge County boundary at Panther Gap. Millboro Shale section measured August, 1966.